Lower Yakima Valley Groundwater Management Program

Volume I

The Program

June 20, 2019

LOWER YAKIMA VALLEY

GROUNDWATER ADVISORY COMMITTEE

This program reflects the work of the Lower Yakima Valley Groundwater Advisory Committee. This program was approved June 20, 2019.

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In remembrance of our GWAC members who are no longer with us, but who helped shape our path.

David Cole

Jim Trull

Table 1 – Active Participants

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Executive Summary

The Lower Yakima Valley Groundwater Management Area (GWMA) was formed in 2012 to address the goal of reducing nitrate concentrations in groundwater. A recent groundwater study in the Lower Yakima Valley, which sampled over 150 private domestic wells in 2017, found 20 percent of the wells consistently exceeded the drinking water standard (USGS 2018).

While many sources contribute to nitrates in groundwater, data from these wells indicate that human activities at the land surface have affected water quality.

One objective of the Lower Yakima Valley Groundwater Advisory Committee (GWAC), also formed in 2012, was to develop a program that would achieve the goal of reducing nitrate levels in groundwater. This document is that program. It describes the committee's completed work, including the committee's decisions, recommendations, and accomplishments. This work is the foundation for the implementation phase.

The GWAC is a large and diverse committee, including representatives from all identified groups affected by groundwater quality, including local, state, and federal government agencies; local citizens; farmers, dairy producers, and agronomists; irrigation districts; conservation districts; environmental groups; and other vested parties. This committee and its workgroups met regularly over the past six years with members committed to resolving issues. The tremendous amount of work produced and the ability to reach consensus on many issues, demonstrates the high level of commitment by the committee members.

Funding

Funding to support the development and planning stage of the GWMA was appropriated by the Washington State Legislature primarily through the efforts of Senator Jim Honeyford of Sunnyside.

Program Content

The program content describes the issue of elevated nitrate in groundwater, how the GWMA was established in the Lower Yakima Valley, and defines the goals and objectives developed for the GWMA. This report explains the environmental and health effects of nitrate in the environment, describes the sources of nitrate, and the different regulatory authorities that affect nitrate in groundwater. Additionally, the report characterizes the Lower Yakima Valley; it discusses the accomplishments and the recommended actions of the GWAC.

Initiatives Completed by the GWAC

Since its inception in 2012, the committee has accomplished the following actions:

- Conducted free well water testing for residents
- Educated the public in both English and Spanish through a variety of outreach methods:
    - Door-to-door discussion and surveys
    - Fact sheets
    - Community fairs
    - Community billboards
    - Website posts
    - Radio public service announcements
    - News releases
- Established a comprehensive database that graphically displays information (GIS)
- Collected deep soil samples from 175 fields (to a depth of six feet)
- Conducted a detailed nitrogen availability assessment to identify the predominant sources of nitrogen
- Collected samples from 159 private domestic wells for six consecutive months to assess drinking water quality.
- Developed sampling plans for all future monitoring work
- Installed 30 monitoring wells for monitoring of long-term ambient groundwater quality
- Compiled Best Management Practices (BMPs) for agriculture and livestock activities
- Developed alternative management strategies to reduce nitrate loading to groundwater from a variety of sources

Recommendations and Alternative Management Strategies.

Through the workgroups and other contracted work, the GWAC identified over 250 potential alternative management strategies that could reduce nitrate concentrations in groundwater. These are described in Appendix I. The committee discussed each strategy, and reached consensus (Appendix J) and prioritized 65 strategies (see Recommended Actions section). These recommendations include the following action categories, to be implemented by the appropriate local, state, and federal governmental agencies, along with farmers, citizens, and other interested groups.

- Support the implementation phase of the GWMA
- Continue groundwater and soil monitoring
- Promote voluntary source reduction strategies for all nitrate sources
- Continue education and public outreach strategies for all Lower Yakima Valley residents, including homeowners and farmers
- Improve irrigation efficiency
- Develop and support research about innovative nitrate reduction strategies
- Consider incentives that support nitrate reduction
- Explore technology to utilize nutrients as energy
- Enhance and streamline regulatory and enforcement mechanisms
- Maintain the established GIS database

Implementation

The next phase of the GWMA program is implementation. The GWAC's completed work from the assessment and planning phase provides a solid foundation for this next phase. Within this document are specific recommendations for reducing nitrate concentrations in groundwater.

Implementation of recommendations is subject to future funding.

Introduction

The Issue

Groundwater in the Lower Yakima Valley contains elevated nitrate concentrations. Several historic groundwater studies have documented nitrate concentrations in excess of the drinking water standard of 10 mg N/L. A compilation of data collected between 1988 and 2008 indicated that 12 percent of wells tested in the area had nitrate concentrations above the standard (PGG 2011). This information prompted the formation of the Lower Yakima Valley Groundwater Management Area (GWMA). Since then, a more recent groundwater study in the Lower Yakima Valley sampled over 150 private domestic wells in 2017 and found that 26 percent of the wells had at least one of its six samples exceeding the drinking water standard. Twenty percent of the wells sampled consistently exceeded the drinking water standard for all samples collected. Nitrate was not detected in 13 percent of the wells sampled (USGS 2018).

Nitrate is the most prevalent contaminant in groundwater (Spalding and Exner 1993), and there are health effects associated with elevated nitrate concentrations in drinking water (WDOH 2016).

Nitrate impacts to groundwater are common in agricultural areas (Harter 2009). There are many sources that contribute to nitrates in groundwater, including animal and human wastes, fertilizers, plants, and atmospheric deposition. In the Lower Yakima Valley, agriculture is the primary economic and land use activity, and most cropland is irrigated (PGG 2011).

The Response

A GWMA was designated in the Lower Yakima Valley to address the issue of elevated nitrate in groundwater.

Formation of the Lower Yakima Valley GWMA

In 2008, the *Yakima Herald Republic* ran a series of articles entitled "Hidden Wells, Dirty Water" written by Leah Beth Ward, detailing nitrate issues affecting public and private wells. The articles suggested that a lack of coordination between local, state, and federal agencies aggravated the problem. These newspaper articles prompted a series of public meetings hosted by the Environmental Protection Agency (EPA) along with state and local agencies.

In November 2009, the EPA designated the Lower Yakima Valley as an Environmental Justice Community.

In January 2010, EPA issued a finding in support of Section 1431 of the Safe Drinking Water Act to address groundwater contamination. EPA found that groundwater in the Lower Yakima Valley is contaminated. This water is an underground source of drinking water, and contamination may present an imminent and substantial endangerment to human health. (Ecology 2010)

EPA conducted groundwater sampling in February and April of 2010.

A preliminary assessment and recommendations document were developed by a group of local, state, and federal agencies (Ecology, 2010). This report summarized the groundwater issues in the Lower Yakima Valley and identified a number of regulatory options for addressing the elevated nitrate concentrations. These options included establishment of a GWMA, Special Protection Area, Aquifer Protection Area, Sole Source Aquifer, Watershed Management Plan, and Total Daily Maximum Load (TDML). Yakima County Commissioners chose to establish a GWMA, and signed an interagency agreement with Ecology in September 2010.

General provisions for groundwater management areas are described in Chapter 173-100 of the Washington Administrative Code (WAC) and are explained in greater detail in Appendix A.

Goal, Process, Objectives and Tasks

The GWMA was established in 2011. The Groundwater Advisory Committee (GWAC) is a multi-agency and citizen-based group that was formed in 2012. The membership of the committee reflects the diverse interest in groundwater protection and the coordinative nature of the effort. Citizens, representatives from the agriculture, environmental groups, and local, state, and federal government agencies were appointed to bring diverse knowledge and represent different perspectives.

The GWAC held public meetings roughly every other month for six years. Meetings were scheduled in advance with an agenda and subsequent meeting minutes. Decisions were made by seeking consensus. When consensus could not be reached, decisions were made by a minimum of 75% majority with a minority report. The committee chose to use credible data and valid scientific protocols to assist with making decisions.

The committee also formed the following work groups to focus on specific issues:

- Education and public outreach
- Data collection, characterization and monitoring
- Livestock and CAFO
- Irrigated agriculture
- Residential, commercial, industrial and municipal (RCIM)
- Regulatory framework
- Funding

These high-functioning workgroups typically met monthly, and were responsible for reporting back to the GWAC about their work.

The committee developed operating guidelines, which clarified the goals, objectives, and work plan. This document is included in Volume III as an attachment.

Goal

The goal of GWAC is to bring nitrate concentrations in groundwater to below the state drinking water standard.

Process

The process identified to achieve this goal includes the following steps:

- Characterize the area
- Identify the problem and causes
- Establish and agree on a goal
- Delineate alternatives to meet goal
- Choose alternatives
- Implement the plan
- Periodically review the plan

Objectives

The following objectives were developed by the GWAC:

- Data and monitoring
    - Collect existing information into a shared data management system.
    - Establish a long-term groundwater monitoring program.
    - Identify sources of nitrate contamination.
- Problem identification
    - Characterize the nature and extent of nitrate concentrations in groundwater.
    - Identify the sources causing elevated nitrates in groundwater.
    - Identify and describe the activities contributing to groundwater contamination based on scientific data and evaluation.
- Measures to reduce groundwater contamination
    - Develop effective and coordinated Best Management Practices (BMPs) to address specific nitrate sources.
    - Develop strategies for implementing BMPs.
    - Support enforcement of new and existing laws and ordinances.
- Education
    - Establish education programs that promote groundwater protection.
    - Establish clearinghouse for information.
    - Educate private well owners.

- Drinking water systems
    - Assess feasibility of expanding public water supply systems.
    - Consider options to encourage expansion of public water supplies to areas with contaminated groundwater.
    - Assist residents that have contaminated water supplies with access to safe and reliable water supplies.

Further, the GWAC decided that:

- Pollution prevention will be a guiding principle for all work done by the GWAC.
- Participation by the Yakama Nation will be requested and encouraged in a way that is consistent with their sovereignty.
- Participating agencies will maintain their regulatory authority using their own discretion. They will also seek opportunities to coordinate actions and address regulatory gaps.
- The GWAC will seek sustainable funding sources to carry out its mission.

Assuring residents have clean and safe drinking water was a priority. One of the first objectives was to educate people about the problem and provide information on how they could protect themselves.

The GWAC tasked itself with identifying the primary sources of nitrate using scientific data. Another important task was identifying and developing practices that would minimize nitrate concentration of groundwater. To accomplish its tasks, GWAC developed a plan that would recommend strategies for implementing improved practices and providing appropriate education and outreach on health risks and how to prevent exposure.

This document is a summary of the committee's work. It focuses on the decisions that were reached (largely through consensus), the recommendations for future work, and ways to reduce nitrate concentrations in groundwater. Additionally, it highlights the extensive work accomplished over the last six years to characterize the area and establish a framework for implementation.

Tasks

Developing a GWMA program is the primary task. This program describes the elements identified in their work plan to achieve their objectives. Each objective is focused toward meeting the goal of reducing nitrate levels in groundwater to below the state drinking water standard.

This program completes the characterization and planning phase of the GWMA and lays the foundation for the next phase of implementation. The implementation phase will focus on carrying out the recommendations.

Other tasks that support this effort are described in the committee's operating guidelines and are attached in Volume III.

Background

There are many elements that make the Lower Yakima Valley a unique environment. This section (1) describes the physical and jurisdictional boundaries of the GWMA, (2) explains why nitrate in groundwater is a concern, and (3) gives a brief overview of the regulatory authority that exists to manage the resources and activities in the Lower Yakima Valley.

Boundary of the Groundwater Management Area

The Lower Yakima Valley GWMA is located south of Union Gap, north and east of the Yakima River, and west of the Yakima-Benton County line (Figure 1). The northern boundary generally lies on the southern slopes of Ahtanum Ridge, several miles southwest of the Cold Creek Syncline. Its total area is 175,161 acres. The GWMA includes the incorporated communities of Zillah, Sunnyside, Granger, Grandview, and Mabton as well as the rural settlements of Buena and Outlook.

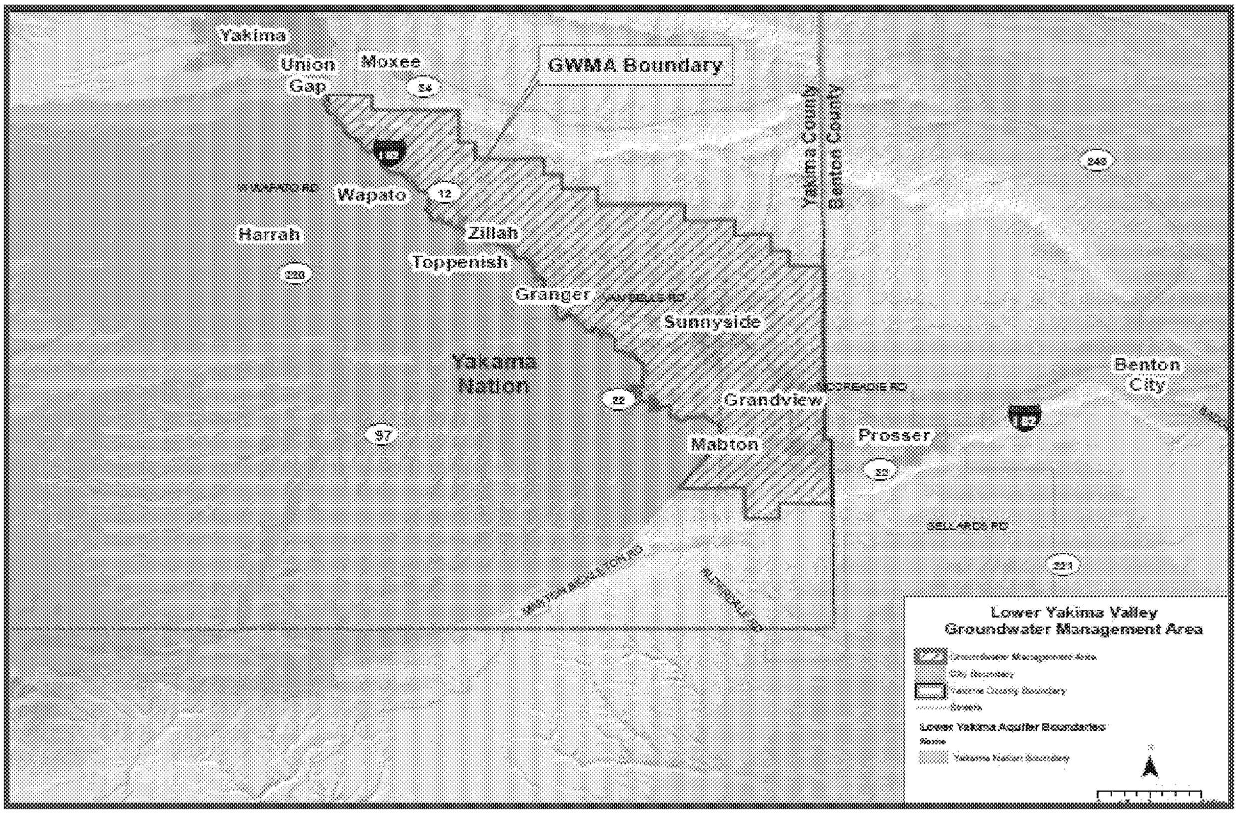


Figure 1 – GWMA Boundary

The Yakama Nation[1] (Figure 2) elected not to include the reservation as part of the GWMA, choosing to address nitrate levels independently. However, they were represented on the GWAC and actively participated in meetings and workgroups.

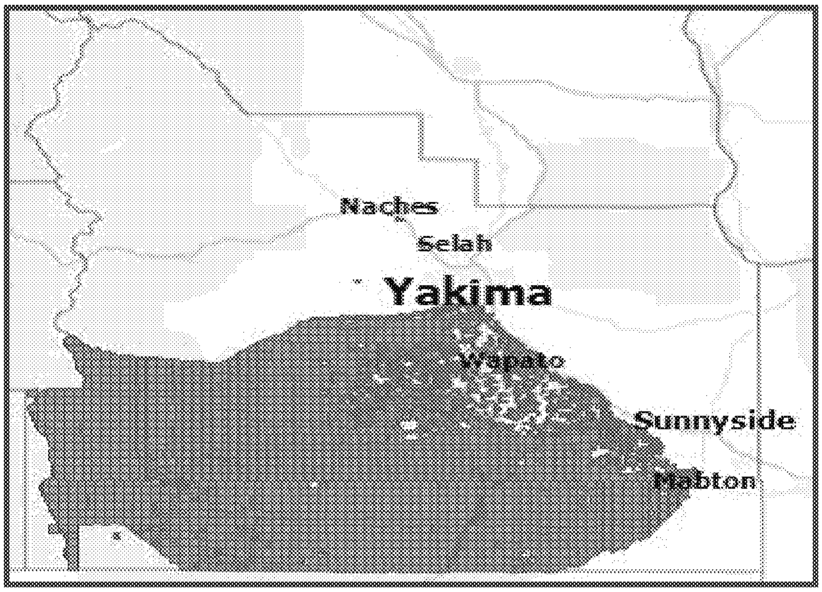


Figure 2 – Yakama Indian Reservation

Jurisdictional Boundaries: Federal, State, Local, and Tribal

The GWMA is within the jurisdiction of Yakima County with the exception of land within the municipalities of Zillah, Granger, Sunnyside, Grandview, and Mabton. While properties owned by the United States exist within the GWMA, they do not present issue areas that relate to the nitrate problem addressed by this program.

Concerns with Nitrate and Drinking water systems

Nitrate has a drinking water standard of 10 mg/L (as nitrogen). This standard is set to protect public health (further discussion on health effects in the section on Nitrogen in the Environment).

Public drinking water supply systems must meet certain criteria established by the Washington State Department of Health. Customers of public water supply systems may be

[1] Confederated Tribes and Bands of the Yakama Nation (Yakama Nation). The Yakama Indian Reservation lies along the southwest side of the Yakima River and extends beyond Yakima County boundaries into the northern edge of Klickitat County and southeastern corner of Lewis County. It covers an area of approximately 1.3 million acres. The Yakama Nation has nearly 9,000 enrolled members from 14 bands and tribes.

exposed to elevated nitrate concentrations in groundwater that exceed the drinking water standard; however, water system operators are required to monitor regularly for nitrate and promptly warn their customers if the drinking water standard is exceeded. If subsequent samples show that nitrate levels continue to exceed the maximum contaminant level (MCL), the state may require a system to implement a permanent solution such as disconnection of a contaminated well, drilling a deeper well into a less contaminated zone of the drinking water aquifer, or treatment.

Private domestic wells are not regulated by the Washington State Department of Health. Users of drinking water systems that are not regulated by the state may be exposed to nitrate levels that exceed the drinking water standard. It is the responsibility of the homeowner or consumer to monitor their own drinking water quality.

How nitrate can get into groundwater

Groundwater contamination is almost always the result of human activity. Any activity that discharges or applies chemicals or water to the land surface may cause impacts to groundwater quality. Water has a natural ability to dissolve and transport materials including contaminants. This also creates an opportunity for groundwater contamination to occur. Figure 3 illustrates water movement in the subsurface. Soils that are permeable will transmit water down into the groundwater. Depending on the nature of the contaminant that has been released into the environment, the contaminant may move with water through the unsaturated zone and into groundwater. Contaminants can also move into the groundwater system through root systems, animal burrows, abandoned wells, and other holes or cracks that create pathways for contaminants to move.

Groundwater moves slowly and so do the contaminants in groundwater. Groundwater velocity is measured in feet per day while surface water velocity is measured in feet per second. Contaminants are generally diluted as recharge water mixes with groundwater; however, since groundwater moves slowly, the amount of mixing and dilution is much less than that of surface water.

Wells that are near a source of contamination are at risk of becoming contaminated. Contamination of groundwater can result in impacts to drinking water, loss of water supply, degraded surface water, and potential health problems. Groundwater is difficult and expensive to clean up. Prevention is the best way to protect groundwater quality.

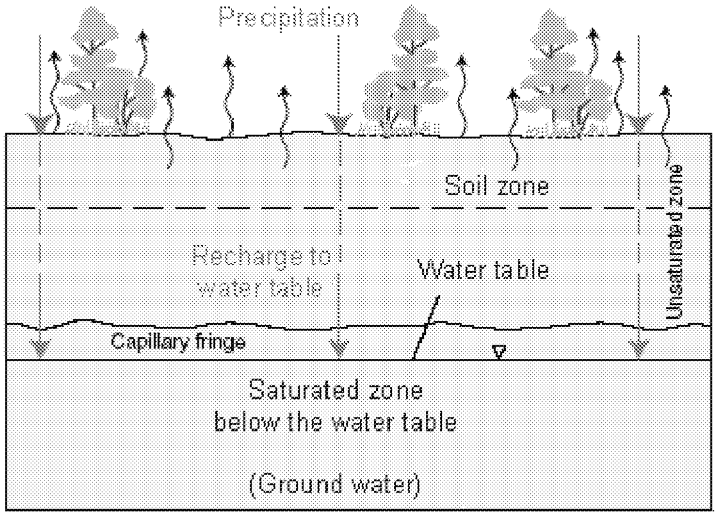


Figure 3 – Water movement in the subsurface.

(Heath, 1983)

Regulatory Authority

There are a variety of regulatory authorities that protect groundwater in the Lower Yakima Valley including local, state, and federal agencies. These authorities cover many aspects of water quality protection. The regulations include groundwater quality and quantity, drinking water, surface water, as well as management of discharges for on-site sewage systems, biosolids, municipal wastewater, industrial wastewater, CAFOs (concentrated animal feeding operations), underground injection control wells, and abandoned wells. Guidelines and technical assistance are also provided for agriculture. Table 1 summarizes the government agencies, their responsibility, and their legal authority. A more detailed explanation can be found in Appendix B.

Table 3 – Summary of Regulatory Authority.

Regulatory Agency	Authority	What it covers	Brief Description
Environmental Protection Agency	Safe Drinking Water Act	Drinking water	Establishes MCLs[1] for drinking water.
	Clean Water Act	Surface water	Authority to regulate discharges to surface water.
Washington State Legislature	Water Pollution Control Act	Protection of water quality	Authority for groundwater quality standards and discharges to surface and groundwater.
	Water Resources Act	Protection of water quantity	Authority for allocating water rights.
Washington State Department of Ecology	Groundwater Quality Standards	Protection of groundwater quality	Establishes numeric criterion, antidegradation and treatment technology standards.
	Surface Water Quality Standards	Protection of surface water quality	Establishes criterion for different water body types and antidegradation.
	NPDES[2] permits	Discharge to surface water	Individual permit for a specific discharge to surface water.
	State Waste Discharge Permits	Discharge to groundwater	Individual permit for a specific discharge to groundwater.
	General permits	Discharges	Covers a large number of facilities with similar features.
	Biosolids Management	Biosolids	Protect human health and the environment where biosolids are managed.
	Well Construction	Standards for installation of wells	Protect water resources by developing construction, installation, and decommissioning standards.
	Underground Injection Control Program	Underground injection control wells	Register and permit underground injection control wells.

Regulatory Agency	Authority	What it covers	Brief Description
Washington State Department of Health	Public Drinking Water Systems	Drinking water	Covers both large and small systems.
	On-site Sewage Systems	On-site Sewage Systems	Establishes regulations for siting, installing, maintaining, and inspecting on-site sewage systems.
Washington State Department of Agriculture	Dairy Nutrient Management Act	Livestock and agriculture	Inspect agriculture and livestock facilities, inventory cropland and facilities.
Yakima Health District	Local ordinances	Wells	Inspect well installation and decommissioning, drinking water quality.
		On-site Sewage systems	Siting, installation, and inspections of residential on-site sewage systems.
Yakima County	Growth Management Act	Land use	Zoning for different land uses.
	SEPA (State Environmental Policy Act)	Proposed activities	Assess environmental implications of potential actions
Natural Resource Conservation Service	Federal assistance	Provide technical assistance	Guidelines for a variety of agricultural activities.
South Yakima Conservation District	Local assistance	Provide technical assistance	Provide assistance to farmers.

1 MCL = Maximum Contaminant Level

2 NPDES = National Pollutant Discharge Elimination System

Organization of this document

The suggested content of a GWMA Program is defined by Chapter 173-100 WAC. The program laid out in the following pages generally follows this structure:

- Nitrogen in the environment
- Sources of nitrate
- Characterization of the area
- Initiatives completed by the GWAC
- Recommended actions

Committee members who have differing opinions with aspects of this plan had an opportunity to file a minority report and have it attached to this document in Volume IV.

Nitrogen in the Environment

Nitrogen is a natural element that can be concentrated in the environment through many sources and activities. It is present in human and animal wastes, plants, fertilizers, and precipitation. Nitrogen exists in different forms and behaves differently depending upon its form. Nitrate is the most mobile form, and moves with water readily through subsurface soils, making it the most prevalent contaminant in groundwater. Elevated nitrate is a concern because it can cause negative health effects.

The transformation of nitrogen in the environment is a complex topic that is described in detail in Appendix C. The appendix includes an illustration of the nitrogen cycle, a description of the numerous forms of nitrogen and its most common forms, a description of the transformation processes, the conditions required, and the environmental processes that affect the transport of nitrate to groundwater.

Nitrate Leaching

Nitrate is soluble in water and moves readily through subsurface soils with precipitation or recharge water. This process is known as *nitrate leaching*. Many factors affect how much nitrate will leach to groundwater, including the type and amount of nutrients applied, when they are applied, the type of crop grown, the type of soils, the climate, the timing and amount of irrigation, and the amount of nitrogen already in the soils (Redding 2016).

Lag Time

Lag time is the amount of time between an action and a response. With land treatment systems, this is the time between when nutrients are applied at the land surface and when they are utilized by a crop, denitrified, or migrate to groundwater. The retention of nutrients in the soil depends on the same factors that affect leaching to groundwater. Typically, there is a lag between when an action is taken at the land surface and the resulting effects on groundwater quality (Meals and Dressing 2010).

There are two components that affect lag time; this includes 1) the vertical component as nitrate transforms and moves downward in the vadose zone, and 2) the horizontal component which considers flow in groundwater from the point where it enters groundwater to reach a measured well. High water recharge rates shorten travel time to a deep water table, but in irrigated areas with high irrigation efficiency and low recharge rates, the transfer to a deep water table may take longer (Harter 2012a).

Health Effects

Nitrate is an acute contaminant, which means a single exposure can affect a person's health. The primary health effect associated with nitrate exposure is the formation of methemoglobin (metHb), which reduces the ability of red blood cells to carry oxygen. This can result in a condition known as methemoglobinemia. While it is normal to have some metHb, adverse effects may appear in children and infants at modest increases in metHb that are otherwise within the normal range for adults (OEHHA 2018). Infants are particularly susceptible because their hemoglobin is more readily oxidized to metHb, they have a higher gastric pH which leads to the presence of nitrate-reducing bacteria, and they have lower concentrations of enzymes capable of converting metHb back to hemoglobin. One of the more serious health effects of methemoglobinemia is cyanosis (the lack of oxygenated blood). Clinical effects can be observed as bluish-grey skin when metHg levels are between 1 and 15 percent, the severity of symptoms increases with increasing metHg levels; a high risk of mortality occurs at levels greater than 70 percent metHg (ATSDR 2017).

Methemoglobinemia in infants is often closely associated with bacterial contamination of well water, which may lead to gastrointestinal infection and diarrhea (Avery, 1999; Powlson et al., 2008). However, other data indicate that infection is unlikely to be the primary cause (Knobeloch et al. 2000) and there is consistent evidence of nitrate as a causative agent in induction of methemoglobinemia. Exposure to nitrate is primarily through consumption of water and food. Because of their susceptibility, it's recommended that infants younger than three months avoid vegetables such as carrots, spinach, and squash, which are naturally high in nitrate. There have been no documented cases of methemoglobinemia in the United States attributed to nitrate in drinking water when nitrogen concentrations were less than 10 mg/L.

Drinking water that exceeds the MCL of 10 mg/L should not be given to infants under 12 months old, and the water should not be used to make formula or juice for them. If an infant shows signs of "blue baby syndrome" (bluish skin, shortness of breath), medical attention should be sought immediately. Women who are pregnant or think they may be pregnant should not drink water that exceeds the MCL. People of any age with certain rare blood enzyme disorders which affect their ability to convert methemoglobin to hemoglobin [glucose-6-phosphate dehydrogenase (G6PD) or cytochrome b5 reductase deficiencies] should avoid drinking water that exceeds the MCL. (WDOH 2016).

Preliminary Assessment

Background information on nitrate in the Lower Yakima Valley was compiled by several government agencies to characterize the issue of nitrate in groundwater and to offer possible ways to address the issue. These agencies included the Washington State Departments of Agriculture, Ecology, and Health; Yakima County Public Works; and the U.S. Environmental Protection Agency (Ecology 2010). The observations and recommendations from this preliminary assessment provided the pathway for the development of the GWMA.

The following are some of the significant findings of this report (Ecology 2010 – Preliminary Assessment):

- Over 2,000 people in the area are exposed to elevated nitrates over the maximum contaminant level (MCL) through their drinking water.

- The population is served by a mix of public and private water supplies. Approximately one third of residents (24,000) rely on private domestic wells for drinking water.
- Nitrate concentrations are greatest in shallow groundwater.
- Typically, private wells draw water from the shallow portion of the surface aquifer. Public drinking water systems tend to rely on deeper wells or a mix of sources.
- Water that exceeds nitrate concentrations may also be at risk of bacterial contamination.
- Agricultural practices, including the use of fertilizer and the management of manure, are linked to nitrate loading and incidents of nitrate contamination in groundwater (Ecology, 2010 – Preliminary Assessment).
- There is a correlation between nitrates and well depth.
- Data were insufficient to determine nitrate trends in groundwater (1990 – 2008).
- The natural level of nitrate is defined as less than 0.3 mg/L. Concentrations below this level have been documented from pristine areas within the Lower Yakima Valley. Concentrations above 0.3 mg/L indicate impacts from human activity.
- The variability in nitrate concentrations throughout the Lower Yakima Valley suggests no clear, uniform trend (increasing, decreasing, or stable) in groundwater.

The following are recommendations from the preliminary assessment (Ecology 2010 – Preliminary Assessment):

- Develop a comprehensive strategy that focuses on assuring long-term access to safe and reliable drinking water supplies for valley residents.
- Initiate education and outreach to help the public make informed choices.
- Test wells.
- Identify the sources of contamination.
- Mitigate the sources of nitrate and bacterial contamination.
- Enforce the existing laws.
- Learn more about the issues.

Owners of private wells who are unsure about their water quality may have their water tested for coliform bacteria and nitrate. The Yakima Health District can advise where to get water tested and has specific recommendations for testing. Many certified labs in Washington charge $20 to $40 per test. If nitrate test results are over 8 mg/L, annual testing is recommended. If results are less than 8 mg/L, testing every three years is recommended.

Nitrates in groundwater can affect both domestic animals and wildlife. This occurs directly by ingestion, or indirectly through impacts to habitats, where groundwater discharging to surface water contributes to nutrient loading of streams, lakes, and wetlands.

Yakima River Surface Water Quality

Scientific studies document the hydraulic connection between the Yakima River and groundwater. The determination of whether a reach is gaining or losing water depends on the local head difference and often changes seasonally (USGS 2009a). Other published USGS studies have documented varying relationships between groundwater and surface water nitrogen within the Lower Yakima Basin (Domagalski et al. 2008; Puckett et al. 2008; McCarthy and Johnson 2009; Tesoriero et al. 2009; Domagalski and Johnson 2011; Domagalski and Johnson 2012).

Temperature, dissolved oxygen (DO), and acidity (pH) are the properties affecting the Yakima River's surface water quality. Nitrogen is an aquatic nutrient in surface water that contributes to algae growth, but it is not included in the Yakima River's surface water quality total maximum daily load (TMDL). TMDL is a calculation of the maximum amount of a pollutant that a water body can receive and still safely meet water quality standards.

Sources of Nitrate

The GWAC identified all significant sources of nitrate in the Lower Yakima Valley. These sources were quantified in a nitrogen availability assessment and include irrigated agriculture; livestock and concentrated animal feeding operations (CAFOs); residential, commercial, industrial, municipal (RCIM) sources; and atmospheric sources.

The Nitrogen Availability Assessment

The Washington State Department of Agriculture (WSDA) completed a nitrogen availability assessment for the GWMA (WSDA 2018). This assessment considered the amount of nitrogen applied to the land surface, the bottom of the root zone, or at the end of the treatment zone. It did not calculate the amount of nitrogen migrating from the land surface to groundwater. Three scenarios were calculated for each nitrogen source by using high, medium, and low estimates, capturing not only typical contributions, but also best- and worst-case contributions.

One of the goals of this assessment was to use as much locally derived information as possible, thereby achieving a refined estimate of the contribution from each of the significant sources.

Data from the assessment are incorporated into the GIS database at Yakima County. The database is intended to be a living document that can be updated as new information becomes available.

A copy of the nitrogen availability assessment (WSDA 2018) is contained in Volume III - Accomplishments. Highlights of the assessment are described below.

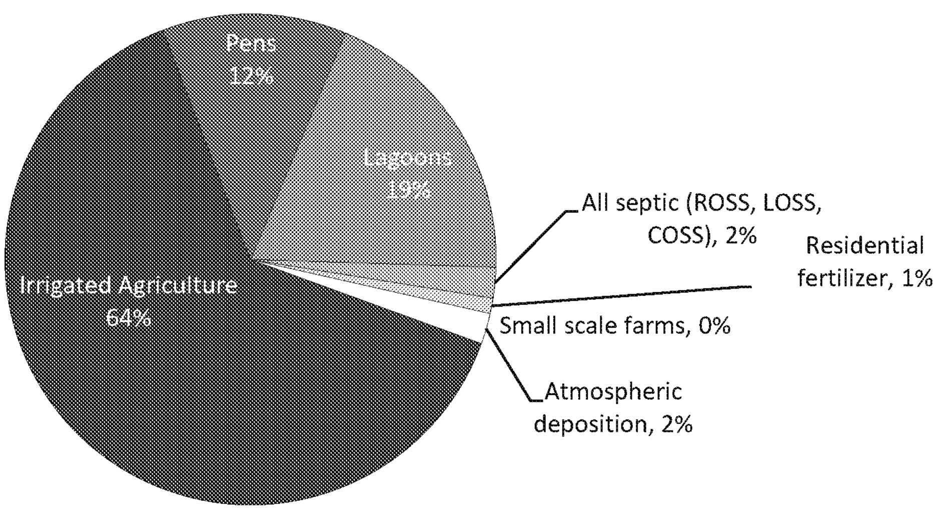
Table 2 describes the nitrogen available for transport from all sources for low, medium, and high scenarios. Figure 4 illustrates the relative percent for medium estimates of nitrogen available in the environment. These numbers were calculated by factoring in the acreage of each source and the amount of nitrogen available. The medium scenario is highlighted because it represents the most likely scenario. The high and low scenarios represent the outer boundaries of what is likely.

Table 4 – Estimated nitrogen available per acre from all sources at the low, medium, and high ranges

Source		Area (acres)	Low Scenario (lb/ac/yr)	Medium Scenario (lb/ac/yr)	High Scenario (lb/ac/yr)
Irrigated Agriculture		85,775	0-58	0-148	0-284
CAFO	Pens	2,096	67	480	892
	Lagoons	210	1,354	7,448	13,542
RCIM	Residential On-site sewage	398	223	403	662
	Large On-site sewage	3	195	209	225
	Commercial On-site sewage	30	163	173	183
	Residential fertilizer	4,381	4.7	11.7	18.6
	Small scale farms	2,096	4.3	10.7	17.1
Atmospheric deposition		87,082	1.53	2.05	6.15

N = nitrogen
CAFO = concentrated animal feeding operation
RCIM = residential, commercial, industrial, municipal
ROSS = residential on-site sewage system
LOSS = large on-site sewage system
COSS = commercial on-site sewage system
(WSDA 2018)

Figure 4 – Nitrogen sources



ROSS = Residential On-site Sewage System
LOSS = Large On-site Sewage System
COSS = Commercial On-site Sewage System.
Source: (WSDA 2018)

Biosolids were not included in this assessment, but their relative contribution is discussed in this section.

When the acreages utilized in the WSDA analysis are summed, the total is greater than the acreage within the GWMA. This is because some acreage has been counted more than once, due to multiple nitrogen inputs. For example, land used for double cropping (silage corn, triticale, alfalfa) and multiple purposes (farming, on-site sewage) have multiple nitrogen inputs. Acreage for which atmospheric deposition has been estimated includes all the GWMA acreage for which WSDA (2018) did not assume that component as part of its estimate (e.g., CAFOs, livestock pens, and manure lagoons). This system was necessary to obtain total nitrogen availability.

Irrigated Agriculture

Irrigated agriculture makes up approximately 85,775 acres (49 percent), of the total land area within the GWMA boundary (WSDA 2018).

Diverse crops are grown in the GWMA. Table 3 lists the top crops in the GWMA, along with the type of fertilizer used. Each crop has a unique cultivation practice.

Table 5 – Summary of fertilizer types used for the top 15 crops in the GWMA.

Crop	Commercial fertilizer (% of acres)	Manure (% of acres)	Compost (% of acres)	Acres using multiple sources (%)
Apple	86.3	0	13.7	0
Corn (silage)	49.6	53.9	0	3.5
Triticale	27.2	74.8	0.8	2.8
Grapes (juice)	91	0	11.6	2.6
Alfalfa	91.8	8.2	0	0
Pasture	97.2	2.8	0	0
Cherry	80.5	0	19.5	0
Hops	97.3	2.7	16	16
Grapes (wine)	100	0	20	20
Pear	76.6	0	23.4	0
Mint	100	0	0	0
Wheat	93.9	22.4	0	16.3
Corn (grain)	71.3	62.6	0	33.9
Asparagus	100	0	0	0
Peach/Nectarine	81	0	19	0

(WSDA 2018)

Crops Supporting Livestock Operations

A significant portion of irrigated agricultural acreage within the GWMA (31,790 acres or 37 percent of irrigated acres, and 18 percent of the GWMA acreage) is dedicated to crops and land uses that support livestock operations. These crops include alfalfa, corn, triticale, and pasture grass.

Triticale is normally used for double-cropping, meaning two crops are grown on the same acreage in one year (WSDA 2018). Triticale is planted in the fall (September – October) and harvested in the spring (April – May). Silage corn is seeded immediately afterward and harvested in late summer or fall (August – October).

Alfalfa is a complex perennial crop. It removes large quantities of nutrients from the soil. It can meet most of its nitrogen needs through fixation of atmospheric nitrogen, but it is dependent both on the presence of rhizobia bacteria in the soil and on whether supplemental nitrogen is added. Alfalfa uses nitrogen from other sources, such as manure or commercial fertilizer, if they are available. The practice of nitrogen supplementation on alfalfa does occur within the GWMA. However, agricultural practices used for perennial crops such as alfalfa and pasture grass remove the majority of the plant residue from the field during harvest or through grazing.

Tree Fruit and Vegetable Crops

The primary crops grown in the region are tree fruits, grapes (both juice and wine), hops, wheat, mint, and asparagus. The orchard and vineyard crops (e.g., apples, grapes, cherries, pears, peaches, and nectarines) are not replanted annually. Rather, they are replanted as appropriate to enhance farming efficiency and anticipate market preference and demand.

Fertilizers

Fertilizers available within the GWMA include commercial fertilizer, manure, compost, and cover crops. There is no accurate current data regarding these four nitrogen sources within the GWMA. Interviews with farmers and crop consultants indicate that the most commonly used product is commercial fertilizer. The exceptions were for corn and triticale, where many acres were fertilized with manure (WSDA 2018).

The timing of fertilizer application can affect nitrogen availability for plant uptake and resultant leaching of excess nitrogen. For instance, commercial fertilizers are formulated to release a specific amount of nutrients at a specific rate over a select period of time. Slow-release fertilizers are designed to release a small, steady amount of nutrients over a course of time. Nitrogen from compost or manure is released over a much longer period of time at a much lower rate. Manure, compost, and commercial fertilizer also react differently at the point of application. Compost or manure adds nutrients and minerals that can improve soil health. These organic nutrients also add structure to the soil which enhances moisture holding capacity and soil biological communities.

Generally, crop fertilizer application choices are affected by several parameters, including fertilizer type, crop nitrogen needs, application recommendations, expected crop pricing, and anticipated yields. They also may be influenced by recommendations from crop consultants and fertilizer guides, historical practices, and practices of other growers in the community. This variability, in combination with effects of fertilizer types used, irrigation type and practices, application timing, soil type and organic matter content, soil nutrient content, manure nutrient content, handling and storage before application, organic carbon cycling and mineralization, and fertilizer fixing in alfalfa will all affect whether or not any fertilizer application represents a nitrogen loading risk. Timing of nitrogen application was not addressed by WSDA (2018) in their nitrogen availability assessment of the GWMA.

High nutrient applications or application of multiple nutrient sources may be used on permanent tree fruit and vegetable crops to improve soil health and maximize fruit production. Producers of crops intended for human consumption may be reluctant to make manure and compost application because of concerns about pathogen transfer, reducing fertilization options (WSDA 2018).

Annual crops such as silage corn, triticale (for silage), and wheat use both commercial nitrogen and manure throughout the GWMA (WSDA 2018). Generally, the nitrogen application for this corn/triticale cropping system is split — one in the fall and one in the spring. Corn (silage and grain) use similar amounts of commercial nitrogen and manure on most of the acreage (WSDA 2018).

Fertilizers of any type should be applied only at an *agronomic rate*; that is, the rate of application that supplies crop nutrient needs to achieve realistic yields, while at the same time minimizing the movement of nutrients to surface water and groundwater.

Commercial Fertilizer

There is no public record of the total amount of commercial fertilizers sold or used within the GWMA. Crop consultants or agronomists are used by the majority of commercial farms operating within the GWMA. These consultants are not usually farmers. They recommend specific pesticide and fertilizer applications across multiple crops on many different farms.

Manure

Manure is a widely used source of organic fertilizer in the GWMA, obtained from CAFOs within the GWMA. While total volume of manure production can be calculated as a function of total animals, no public records exist that explain how much manure is used to fertilize crops and how much is exported to land within or outside the GWMA.

Manure contains two primary forms of nitrogen: ammonium and organic nitrogen. Organic nitrogen is nearly immobile. It becomes mobile and available to crops through mineralization, the process by which soil microbes decompose organic nitrogen into ammonium. The rate of mineralization varies with soil temperature, soil moisture, and the amount of oxygen in the soil. After mineralization, microorganisms within the soil convert ammonium into nitrate. This process, called nitrification, occurs most rapidly when the soil is warm, moist, and well-aerated.

Manure contains high concentrations of organic nitrogen and ammonium and low concentrations of nitrate compared to inorganic fertilizer. It is difficult to estimate nitrogen loading to soil, air, and water from manure application without analysis of nitrogen content.

Compost

Compost is also an organic fertilizer used in the GWMA. Compost supplies organic nitrogen, organic matter and other nutrients and minerals to the soils.

Cover Crops

Cover crops can utilize nitrogen within the soil. However, they can also be a source of nitrogen if plowed back into the soil on-site. The variety of cover crops and number of years of integration of cover crops into the soil can affect overall nitrogen concentrations in the soil.

Water Applications

Irrigation practices can mobilize nitrate in the environment. Excess irrigation water can leach nitrate to groundwater and can affect surface water through field runoff or as irrigation return flows.

Irrigation water requirements vary based on crop type.

Irrigation water can also be a source of nitrate, which should be taken into account when calculating application rates. The average nitrogen concentration of high flow (late spring) and low flow (late summer) conditions of the Yakima River at Kiona during the 2012 irrigation season was 0.809 mg/L (USGS 2013). Groundwater quality varies dramatically across the GWMA.

Irrigated agriculture is mapped statewide by WSDA, including the area within the GWMA. There is no current data regarding the distribution of the three general irrigation methods (sprinkler, drip, rill) within the GWMA. Interviews with farmers and crop consultants indicate that sprinkler irrigation was used on 61 percent of the total irrigated acreage in the GWMA, and drip irrigation (including drip, micro sprinkler, drip/sprinkler, and combinations) was used on 23 percent of the acreage. Rill irrigation was used on 15 percent of the acreage (WSDA 2018).

Silage corn and triticale cultivation is almost all irrigated with sprinkler or center pivot irrigation systems. Triticale cultivation rarely occurs on rill-irrigated fields (Sheehan, pers. comm.).

Livestock Operations/CAFOs

CAFOs are concentrated animal feeding operations for the cultivation of livestock or livestock products. These include dairy, beef, pigs, chickens, and other products.

A 2012 assessment of dairy operations in Yakima County estimated there were 99,532 milk cows on 97 farms (WSDA 2018). The majority are located within the GWMA. CAFOs are increasing in size, while the number of farms is decreasing (WSDA 2018).

For the purposes of this report, livestock operations and CAFOs can contribute nitrogen from pens, corrals, compost areas, and lagoons. Land application of manure from these operations is considered in the irrigated agriculture section.

Manure and other animal by-products contain nutrients that are beneficially reused to grow crops. They increase soil fertility and crop yield, and their use is a historic practice. Manures are recommended over commercial fertilizers where there is a desire to build the soil profile by increasing and diversifying soil organisms, increasing moisture holding capacity, and reducing the need for inputs.

Livestock operations have the potential to release nitrate, chloride, sulfate, and bacteria to surface or groundwater (Harter et al. 2002; Harter and Lund 2012). Impacts to groundwater depends on contaminant characteristics, nutrient and water management practices, climatic conditions, soil types, the geology, and groundwater characteristics (Viers et al. 2012). Nitrogen sources can be animal holding areas, manure storage impoundments (either lagoons or settling ponds/basins), and manure applications to cropland (Harter et al. 2002).

The national statistical average of manure production of milk cows (in 2000) was 15.24 tons per animal unit of manure excreted per year. The national statistical average of nitrogen per ton of manure excreted is 10.69 pounds of nitrogen per ton (Kellogg et al. 2000). The formulas used by the Washington State Department of Agriculture (2010) to calculate animal manure production, nitrogen production, and losses due to volatilization or denitrification for Holstein cows are as follows:

- **Annual manure production** is calculated using the following formula:

  [[(number of milking cows) (1.4) (108)] + [(number of dry cows) (1.4) (51)] + [(number of heifers) (0.97) (56)] + [(number of calves) (0.33) (83)]] (365)/2000

- **Nitrogen production** is calculated using the following formula:

  [[(number of milking cows) (1.4) (0.71)] + [(number of dry cows) (1.4) (0.3)] + [(number of heifers) (0.97) (0.27)] + [(number of calves) (0.33) (0.42)]] (365)/2000

- **Losses due to volatilization** during storage are estimated at 35 percent. This does not include application losses.

Waste Storage Facilities (Lagoons)

Liquid manure stored in lagoons can be a source of nitrogen and other contaminants. Contents of lagoons often consist of liquid manure (including urine), rainfall, snowmelt, and any liquid diverted from production areas. Design, construction, and management of lagoons are important for protecting groundwater. In studying lagoons, researchers found substantial variation in the composition of solids, liquids, and dissolved constituents; they also found leakage rates causing a wide variation in the potential to affect groundwater quality (Ham 2002; Harter and Lund 2012a).

Lagoons include impoundments, settling basins, settling ponds, and ponds. There are a wide variety of construction and operational techniques for lagoons; some are earthen impoundments that are drained and cleaned as needed, while others are concrete lined, engineered basins.

Lagoon nitrogen concentration depends on farm practices and unit operations on site. Operational differences are often related to the type of solids separation systems utilized. Other factors include whether irrigation water is mixed with liquid manure for land application and potential seasonal effects.

WSDA (2018) conducted lagoon assessments on 115 lagoons in the GWMA, inspecting each lagoon when it was nearly full and again when it was nearly empty. This assessment allowed WSDA to determine average lagoon capacity, depth, and surface area. These measurements were used to calculate discharge using Darcy's Law. Assumptions were necessary to determine liner permeability and thickness. Nitrogen loading was calculated using a total nitrogen concentration of 1,053 mg N/L.

Pens and Corrals

Animal confinement systems include pens, corrals, and freestalls, as well as resting, feeding, and housing areas. These areas are typically unvegetated and vary depending upon the animal type and the individual livestock operation. WSDA (2018) estimates that there are 1,597 acres of dairy CAFO pen area and 499 acres of nondairy CAFO pen area, for a total of 2,096 acres of pens in the Lower Yakima Valley.

Pens and corrals can have a surface of unlined and compacted soil or concrete. Over time the soil becomes compacted, which decreases the permeability. Manure accumulating on the surface mixes with the soil layer and forms a low permeability interface layer that reduces the permeability of corral and pen surfaces (Harter and Lund 2012a). Nitrogen loading from corrals and pens at CAFOs is governed by engineered sloping, catch basins, soil type, feedlot age, unsaturated zone thickness, stocking rate, rainfall, and evapotranspiration rates. In some situations, increased short-term leaching in corrals may occur due to cracking during seasonal weather events. The nitrogen loading rates of pens varies depending upon number and size of stock and management. Nitrogen leaching potential in pens and compost areas is controlled by precipitation, management of manure in the pen areas, and compaction by livestock or equipment.

Animals may spend time in freestall barns, milking parlors, or loafing sheds. These facilities are built with concrete floors and are cleaned multiple times a day. Potential leaching from these types of buildings, even anticipating cracks in concrete floors that could provide a pathway to leaching, is less likely than leaching from pens and lagoons.

Compost Areas

There are 536 acres associated with composing activities (WSDA 2018). "'Composting' means the biological degradation and transformation of organic solid waste under controlled conditions designed to promote aerobic decomposition. Natural decay of organic solid waste under uncontrolled conditions is not composting." (WAC 173-350-100). Composting may refer to a category of activities rather than a specific practice or technology. These activities include composting in bags, spreading material out over a concrete pad or large surface area to dry, turning frequently, and adding moisture to material that has dried out. Composting reduces the weight of the basic material. Compost is used by organic growers to amend soil structure, density, and nutrients, as well as to prevent weeds.

Residential, Commercial, Industrial and Municipal Groundwater

Non-agricultural sources of nitrate within the GWMA boundaries include on-site sewage systems used for residential or commercial purposes, biosolids, residential lawn fertilizer use, hobby farms, underground injection control wells, and abandoned wells.

Residential On-site Sewage Systems

Residential On-site Sewage Systems (ROSS) are more commonly found in the rural areas of the GWMA, which are not served by municipal sewage collection and treatment systems. On-site sewage systems collect and treat wastewater generated by a residence. Wastewater from the house is collected in a on-site sewage tank where solids settle and remain in the tank. The liquid portion flows into the drainfield and infiltrates the ground.

There are 6,044 residential households within the GWMA that discharge wastewater to an on-site sewage system (WSDA 2018). The contribution from ROSS was calculated based on assumptions of the number of people per household and the amount of nitrogen and liquid generated per person each day. Assumptions were also used to estimate nitrogen losses. WSDA (2018) estimates between 7 to 17 grams of nitrogen are discharged into an on-site sewage system every day, which equates to a concentration of 26 to 75 mg N/L. The average concentration is 11 grams N/person/day or 50 mg N/L.

Minimum land area requirements for on-site sewage systems are established in WAC 246-272A-0320. The land area depends on the type of water supply and the soil type. The minimum area ranges from 12,500 square feet (3.5 houses per acre) to 2.5 acres.

The highest density of on-site sewage systems is within and near urban growth areas associated with municipalities. All of the densities meet the most stringent minimum land area requirements with an average land area ranging between over 12 acres per ROSS to 6.4 acres per ROSS.

- The highest density of on-site sewage systems is found on the east and north side of Sunnyside, where the density of on-site sewage systems ranges from 80 to 100 on-site sewage systems per section (average land area ranges from 8 acres to 6.4 acres per ROSS).
- West of Sunnyside, near Outlook, on-site sewage system density approaches 80 systems per section (average land area 8 acres per ROSS).
- In the Zillah to Buena area, density approaches 80 systems per section (average land area 8 acres per ROSS).

- Slightly lower on-site sewage system density is found south of Grandview, Sunnyside, and Mabton where the on-site sewage system density ranges from 50 to 70 per section (average land area ranges from 12.8 acres to 9.1 acres per ROSS).

Many residents that use on-site sewage systems to treat their wastewater also have a private domestic well for their source of drinking water. The proximity of a well to an on-site sewage system or a large density of homes using on-site sewage systems can cause impacts to local groundwater quality and can affect drinking water quality for residents. For example, in the Buena community within the GWMA, failing on-site sewage systems and related contaminated wells caused Yakima County to respond with grant-funded installation of a public water system and a wastewater treatment system utilizing a combined on-site sewage /sewer system (Redifer 2014).

The frequency of on-site sewage tank pumping for each residential on-site sewage system in the GWMA is unknown. In a survey conducted by Yakima County 82 percent of 458 surveys collected indicated that they had their on-site sewage tank pumped recently.

The predominant soil types underlying the ROSS drain fields located within the GWMA are characterized as silt loams that are porous and have a well-developed structure. The estimated depth to groundwater is equal to or greater than 10 feet at approximately 90 percent of the ROSS locations (see Figure 12, Depth to Groundwater).

Large On-site Sewer Systems

A large on-site sewer system (LOSS) serves multiple residences or establishments, serving twenty or more people per day or having a design volume of over 3,500 gallons. Washington State Department of Health records show that there are two of these systems located within the GWMA. One system is located outside of Zillah with a design capacity of 5,000 gallons. The second is located outside of Granger with a design capacity of 4,850 gallons. Annual LOSS reports are submitted to the DOH.

Commercial On-site Sewer Systems

A commercial on-site sewer system (COSS) is used for employees working at agricultural businesses or other businesses that operate year round and are not classified as a LOSS by the DOH. These locations include wineries, schools, agriculture packing lines, small businesses (e.g., stores and fire stations), agricultural business offices, maintenance buildings, churches, and confined animal feeding operations (CAFOs).

Biosolids

Biosolids are a nutrient-rich soil amendment derived from public waste treatment plant septage. Septage is a class of biosolids that comes from on-site sewage tanks, treatment works, and similar systems receiving domestic wastes (WAC 173-308-050). Biosolids are produced by treating sewage sludge to meet certain quality standards that allow it to be applied to the land for beneficial use.

Biosolids are permitted for use on 6.5 percent (11,346 acres) of the total GWMA (175,000 acres), but only 0.8 percent of the GWMA (1,393 acres) have received biosolids applications from 2010 through 2017 (figure 5). Ecology requires soil testing of the top 3 feet of soil and restricts application of biosolids based on the cumulative soil nitrate value and the crop grown (Severtson 2017).

Figure 5 – Biosolids Application Sites

Residential Lawn Fertilizers

Residents use lawn fertilizers for the care and maintenance of their lawns. Not all residents fertilize their lawns. There is no available data about the frequency or amount of fertilizer used by residents. WSDA (2018) used assumptions to estimate the amount of nitrogen that might be applied to residential lawns within the GWMA.

Other factors that could affect nitrogen availability are irrigation and whether lawn clippings are removed or left on the lawn.

Hobby Farms

Hobby farms are defined as minimalist agricultural entities on parcels of land measuring less than 10 acres that are operated without the intention of profit. These farms may also be a source of nitrogen depending upon the individual practices. Nitrogen contributions on these parcels may come from individual gardens, pastures, pets, and other animals.

Underground Injection Control Wells

Underground injection control wells are typically located in roadways for stormwater management.

Abandoned Wells

Abandoned or improperly constructed wells can be a direct conduit for contaminants to reach the groundwater.

Atmospheric Deposition

Atmospheric deposition of nitrogen is the process by which aerosol particles collect or deposit themselves on the earth's surfaces. It may be either wet or dry deposition. Nitrogen emissions may come from transportation, agriculture, power plants, industrial, and natural sources. In agricultural areas, emissions from operations involve animals or fertilized cropland. Emissions may travel from very long or very short distances (Viers et al. 2012). Deposition monitoring is conducted by the National Atmospheric Deposition Program. There is one monitoring station in Eastern Washington, in Whitman County (WSDA 2018).

Legacy Nitrogen

Legacy nitrogen is the residual nitrogen that accumulates in soil after the growing season. Portions of the nitrogen retained in the soil are in the form of organic nitrogen, which mineralizes slowly over time. There is also residual nitrate that can migrate to groundwater with recharge. The amount of residual nitrogen in the soil of the Lower Yakima Valley is unknown. Research on the topic of legacy nitrogen indicates that the amount of stored nitrogen may be significant in agricultural areas and may take a long time to be converted or utilized. However, some studies have documented rapid improvements based on implementing Best Management Practices (Sebilo et al. 2013; Rudolf et al. 2015; Dalgaard 2014; Exner et al. 2013; Van Meter et al. 2016).

Farming practices have made improvements over the years in how nutrients, water and chemicals are applied. It is unclear how the lingering effects of historical practices effect water quality and it is unclear how the improvements in farming practices translate into improvements in water quality. No scientific studies within the GWMA area were presented or considered by the GWAC to evaluate legacy effects on water quality.

Characterization of the Area

The following section is a description of the Lower Yakima Valley Groundwater Management Area (GWMA) with a focus on 1) physical basin characteristics, 2) land and water use, and 3) population demographics. This information relates to Yakima County in some instances and only to the GWMA in other instances.

Physical Basin Characteristics

Physical basin characteristics described in this section include: geology, hydrogeology, topography, depth to groundwater, soil, and climate.

Geology

The primary geologic features discussed include the stratigraphic units of the Columbia River Basalt Group, the Ellensburg Formation, and the Lower Yakima Valley Fill. A more detailed description of the geology is contained in Appendix D.

Columbia River Basalt Group

The Columbia River Basalt Group (CRBG) is a thick sequence of Miocene eruptive basalts estimated to be several thousand feet thick and interbedded with a few minor sedimentary strata. It is subdivided into three primary formations: the Saddle Mountains Basalt, the Wanapum Basalt, and the Grande Ronde Basalt (USGS 2009a; GSI 2009a, 2011). The Saddle Mountains Basalt is often exposed at the surface, with thicknesses ranging from 180 to 800 feet and averaging more than 500 feet in the Yakima Basin.

The Ellensburg Formation

The Ellensburg formation was formed from lava debris created during volcanic activity. The debris are sedimentary materials that were deposited upon the lava plain, transported by eastward flowing streams or aeolian processes moving ash and pumice (USGS 1962). The majority of the volcanic materials were deposited upon the lava plain after these flows ceased and the Cascades continued to rise (USGS 1962, 1999a).

The Ellensburg Formation consists primarily of semi-consolidated clay, silt, and sand with only small amounts of gravel and conglomerate. It often appears as sedimentary interbeds found between the various CRBG formations, members, and flow units. These interbeds vary in nature and composition, typically ranging between 1 and 100 feet thick. (USGS 1962).

Lower Yakima Valley Fill

The Lower Yakima Valley fill are a variety of fine and coarse-grained sediments overlying the Ellensburg Formation (USGS 2009a). These sediments were depositied about 16,000 years ago during the glacial outburst floods created by Lake Lewis. The water in Lake Lewis remained for undefined periods before draining through Wallula Gap, permitting surface loess and basalt materials collected in the flood's transit southeast from the Spokane area to settle to the lake's bottom. This settled material formed at least some of the fine-grained gravelly and sandy materials extant today on the valley bottom of the Yakima River within the GWMA (Figure 6).

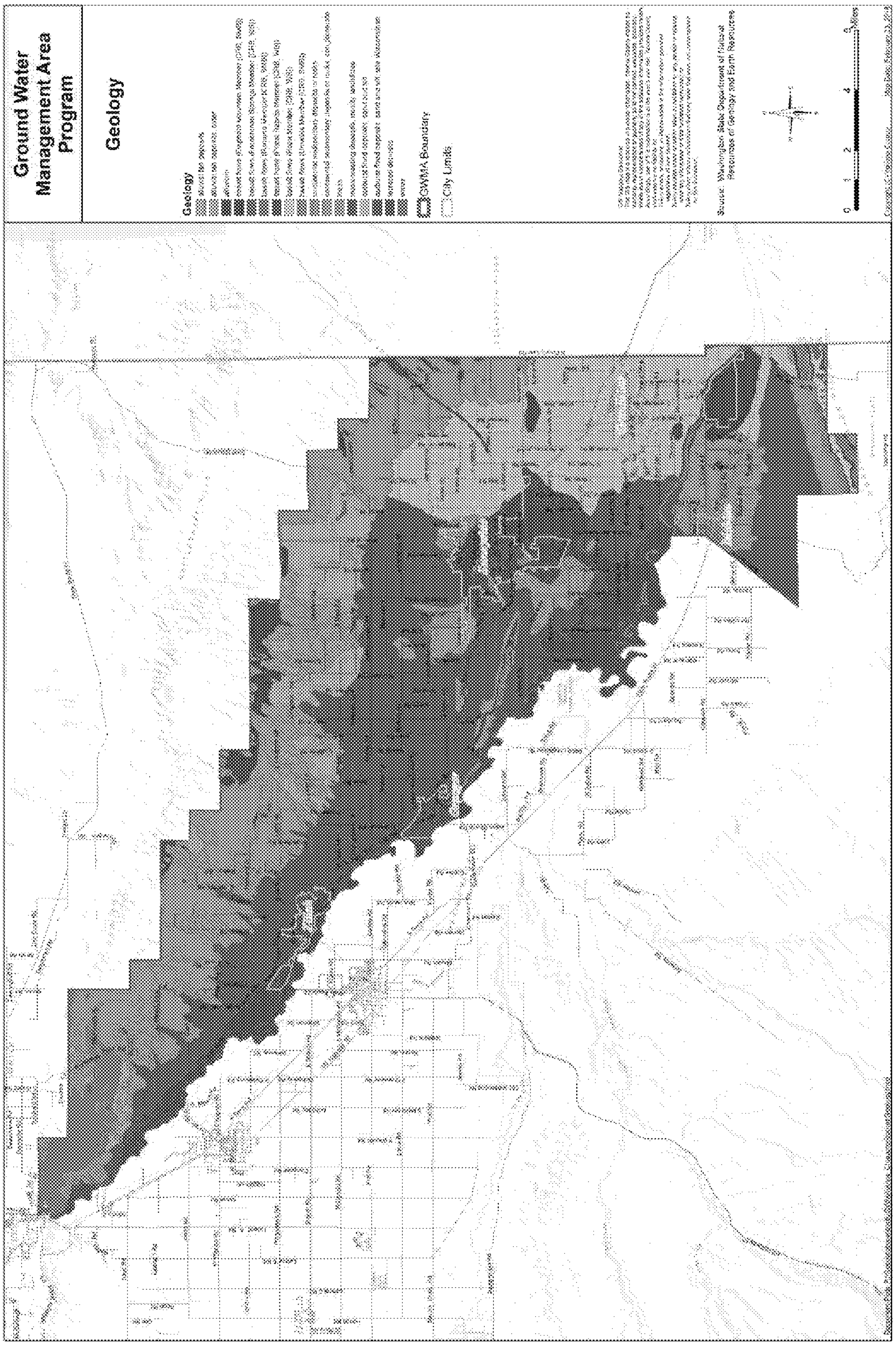


Figure 6 – Geology

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Hydrogeology

The geologic framework and some of its hydrogeologic units of the Columbia Plateau regional aquifer system were described by Drost and others (USGS 1990b). The aquifer system consists of a large thickness of basalt made of numerous flows with minor interbedded sediments (USGS 1990b). The principal water-bearing zones in the basalt sequence are those upper parts of certain flows rendered relatively permeable by weathering, jointing, and vesicularity (USGS 1962).

The physical characteristics of the materials within the hydrogeologic units of the GWMA are described by the U.S. Geological Survey (USGS) (see Table 1 in USGS 2009a). The units have various consolidated or unconsolidated structures. The unconsolidated units include alluvial, alluvial fan, terrace, glacial, loess, lacustrine, and flood (Touchet Beds) deposits that range from coarse-grained gravels to fine-grained clays, with some cemented gravel (Thorp gravel and similar unnamed gravels). Most of the unconsolidated units consist of coarse-grained deposits. The consolidated units are principally deposits of the Ellensburg Formation, but also include some undifferentiated continental sedimentary deposits. These units include continental sandstone, shale, siltstone, mudstone, claystone, clay, and lenses or layers of un-cemented and weakly to strongly cemented gravel and sand (conglomerate). These clastic deposits are one of the most stratigraphically complex parts of the aquifer system (USGS 2009a).

Most domestic wells are completed in the sediments above basalt. There are several basalt wells providing domestic water supply along the northern fringe of the project area. Figure 7 shows the surface hydrogeologic units within the GWMA (USGS 2009a).

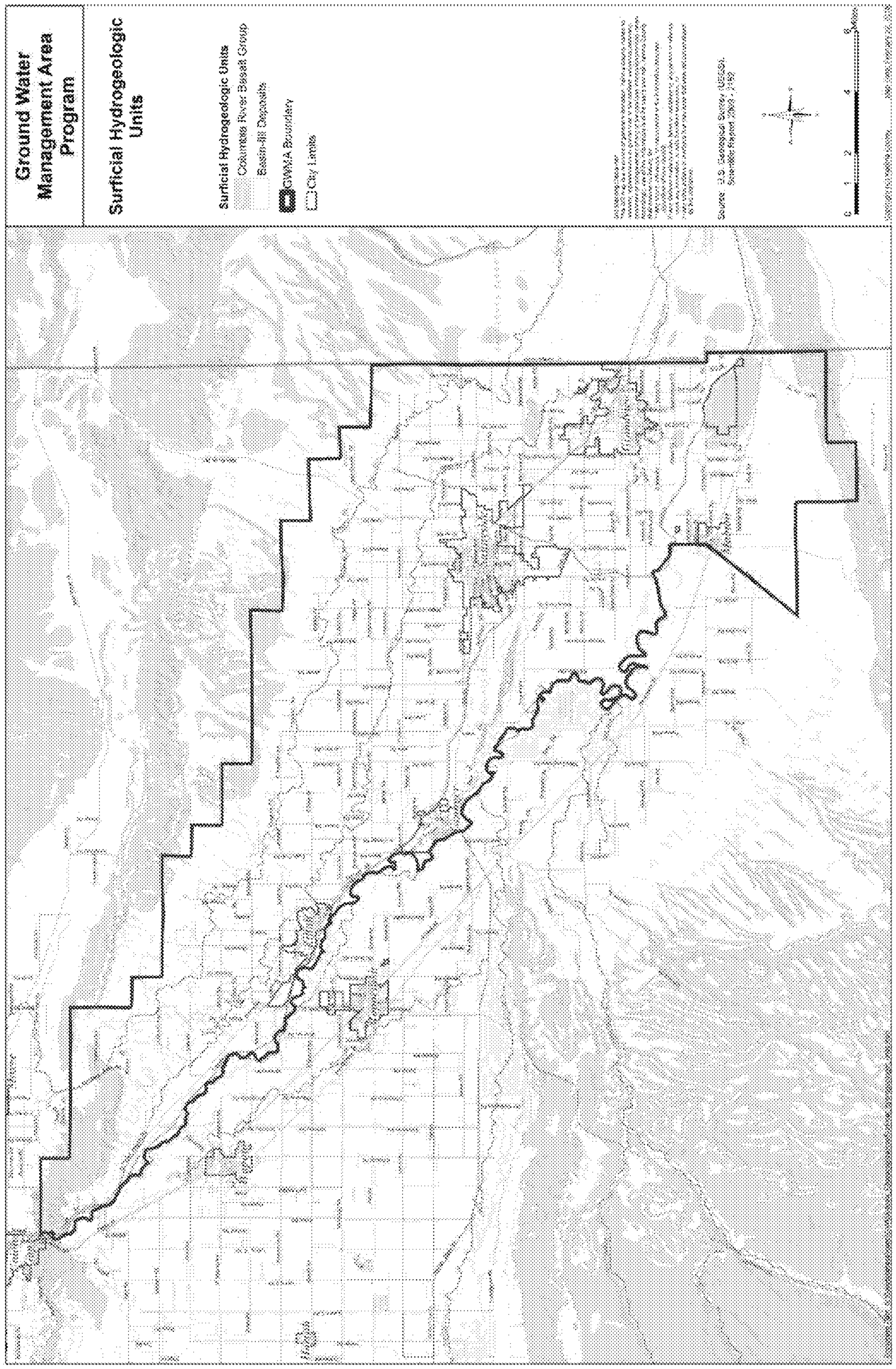

Figure 7 – Surface Hydrogeologic Units

Aquifers

An aquifer is a water-bearing layer of rock that will yield water in a usable quantity to a well or a spring. There are generally two kinds of aquifers: confined and unconfined.

In 2009, the USGS published a study of the hydrogeology of aquifers in the Yakima River Basin. The study found that there are two main aquifer types in the GWMA. The first is a surface unconfined to semi-confined alluvial aquifer. This aquifer is composed of highly layered alluvial material with predominantly silt, sand, and cobbles with a total thickness of up to 500 feet (USGS 2009a). The second aquifer is an extensive basalt aquifer of great thickness underlying the surface aquifer. The basalt aquifer is believed to be semi-isolated from the surface aquifer and stream systems.

Natural groundwater flow within the shallower surface aquifer generally follows topography, but may be locally influenced by irrigation practices, ponds, lagoons, drains, ditches, and canals. Groundwater in this shallower aquifer generally flows toward the Yakima River (USGS 2009a) and is used locally for irrigation and residential water supply.

Porosity is the ratio of the volume of interstices of a material to the volume of its mass. Natural rock materials differ in porosity. The porosity of some consolidated rocks, such as tightly cemented sandstone or massive lava flows, is only a few percent or even a fraction of a percent. The porosity of some clays may exceed 50 percent. The well-sorted materials in unconsolidated rocks, such as clay or clean, even-textured sand or gravel, have very high porosity. Poorly sorted materials, in which the smaller particles fill the openings between the larger grains, have low porosity.

Both confined and unconfined aquifers are present within the GWMA. A confined aquifer is a water-bearing stratum that is confined or overlain by a rock layer that does not readily transmit water or that is impermeable. An artesian aquifer is a confined aquifer where the groundwater is under positive pressure. This positive pressure causes the water level in a well to rise to a point where hydrostatic equilibrium has been reached.

Unconfined aquifers are those into which water seeps from the ground surface directly above the aquifer. An unconfined aquifer, also called a water table aquifer, is an aquifer that has the water table as its upper boundary, and where the pressure is equal to the atmospheric pressure.

The *potentiometric surface* (static level) is the level to which water rises in a well. In a confined aquifer this surface is above the top of the aquifer unit. In an unconfined aquifer, it is the same as the water table, or groundwater level.

The amount of water entering and exiting the aquifer can affect the potentiometric surface of the aquifer. Inputs to the aquifer system include infiltration of water from precipitation, irrigation, or wastewater sources. Outputs from the aquifer may include pumping of wells or surface water discharge. A variety of factors affect groundwater in the Lower Yakima Valley, including precipitation, irrigation, wastewater discharges, surface water interactions, pumping of wells, and the presence of irrigation canals.

Figure 8 shows the location of known springs within the Toppenish Basin (USGS 2009a).

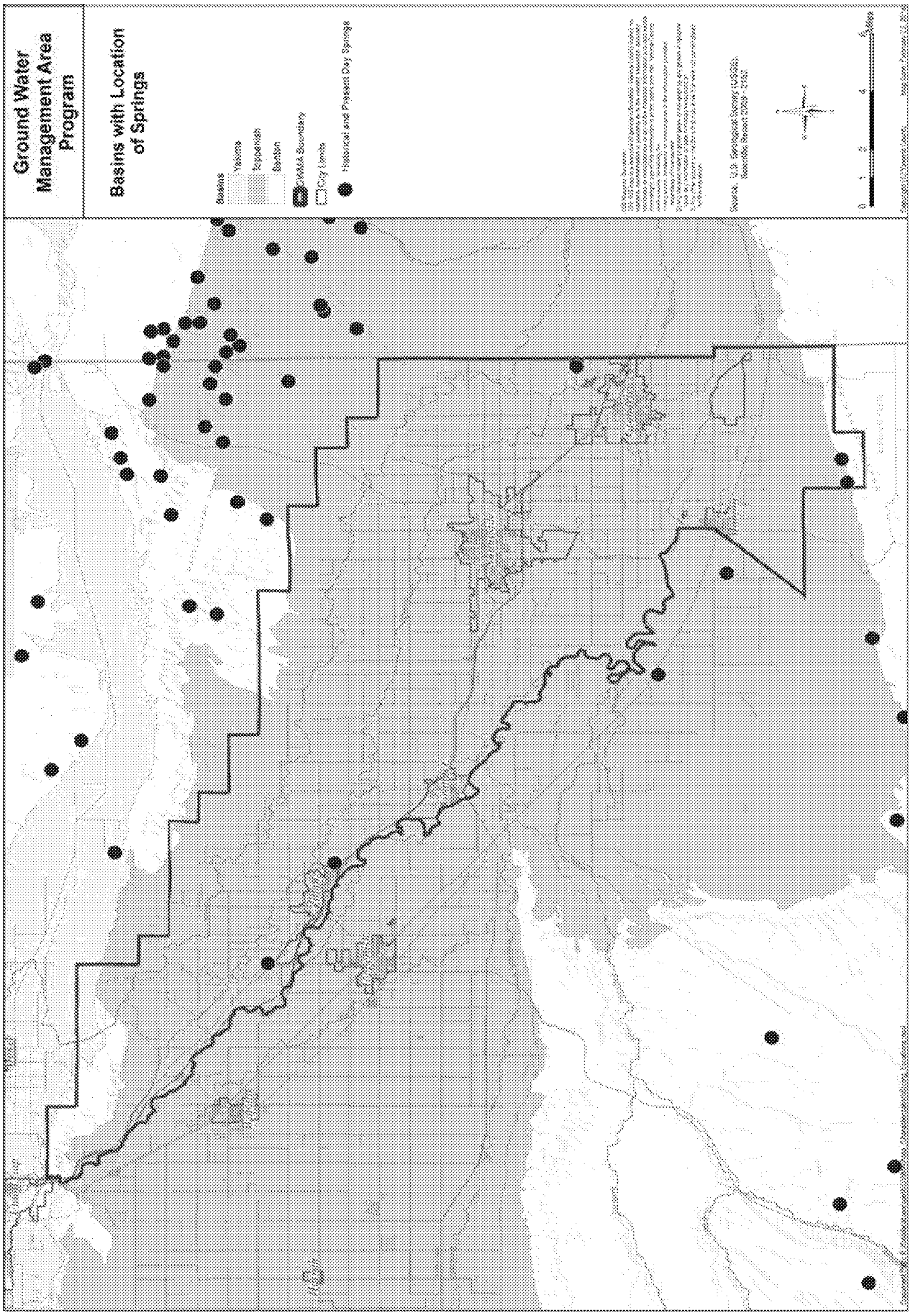

Figure 8 — Springs within the Toppenish Basin

Groundwater Recharge

Groundwater recharge is a hydrologic process where water moves downward from the land surface to groundwater. Recharge is the primary method through which water enters an aquifer. Recharge includes all infiltration sources, including precipitation, surface water, irrigation water, and wastewater.

The delivery and use of surface water in the irrigation districts results in a source of recharge (10 to 20 inches per year) from water that infiltrates into the ground and migrates past the root zone and into groundwater. The USGS established recharge rates by a one-day time-step model, utilizing the daily inputs from 25 years (1959 – 2001) of historical records, taking evapotranspiration of plants (Vaccaro 2016; USGS 2007a). Figure 9 shows the mean annual recharge of the surface aquifers within the GWMA, based on Figure 10 of the USGS report (2007a). USGS calculated the specific discharge for each model cell, and could readily provide a GIS coverage or MODFLOW input file with those data. The ranges shown in Figure 10 of the USGS (2007a) report were chosen to facilitate illustration of the estimates for the entire study area. The methods used to estimate recharge are clearly documented in the USGS report. A better estimate of current recharge could be made using the additional detailed information if those data were made available.

A more detailed description of Vaccaro's discussion on recharge (2016) can be found in Appendix D.

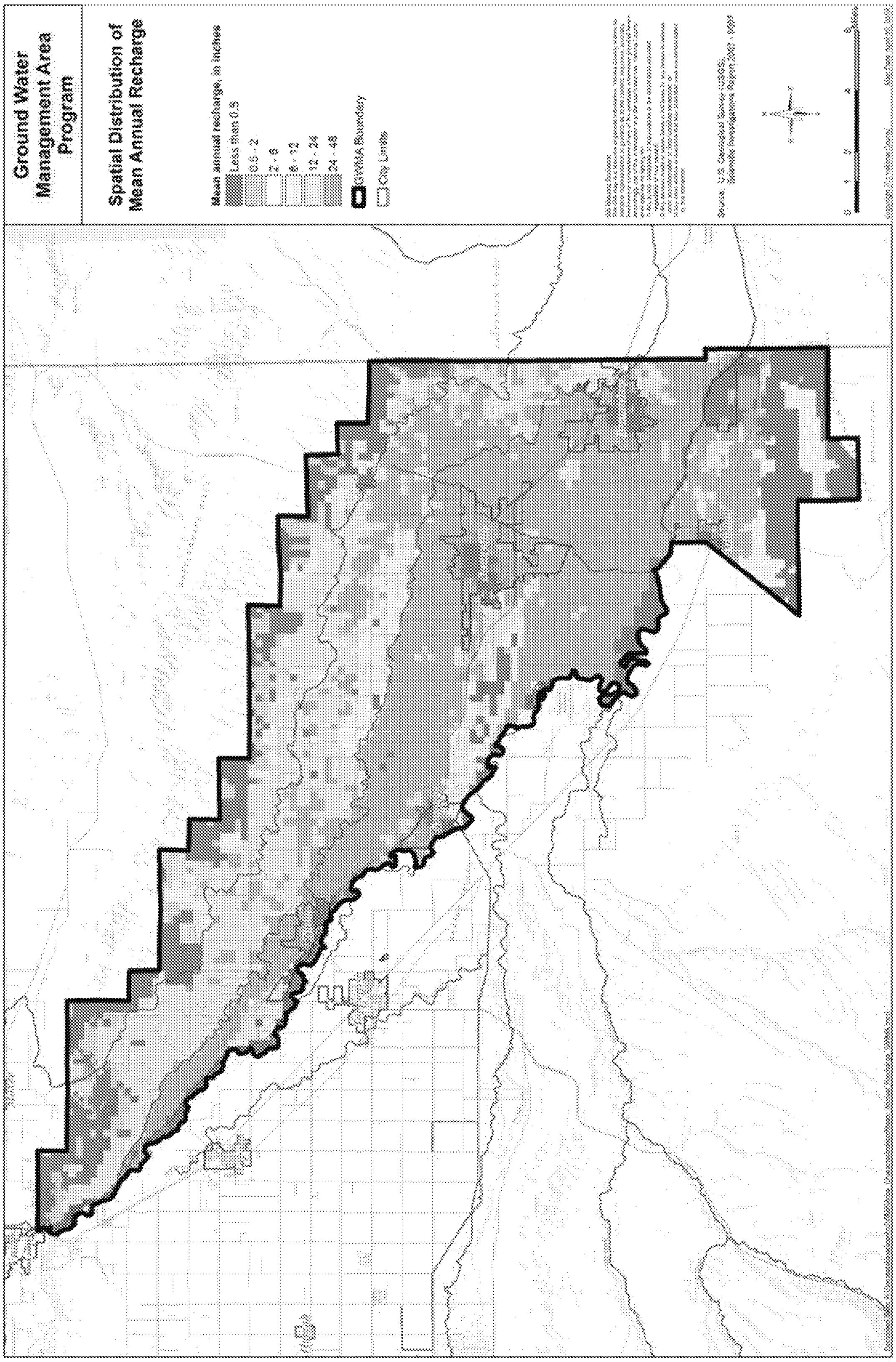

Figure 9 – Mean Annual Recharge within the GWMA

Groundwater Flow

There are two main aquifers underlying the area bordered on the north by the Ahtanum Ridge, on the south by the Toppenish Ridge, and bisected by the Wapato Syncline (USGS 2009a). These include a surface unconfined to semi-confined alluvial aquifer and a basalt aquifer underlying the sedimentary deposits (USGS 2009a). The basalt aquifer is believed to be semi-isolated from the surface aquifer and stream systems. Groundwater flow generally follows topography towards the Yakima River. It is likely that the minor components of flow are enhanced by irrigation practices upland from the Yakima River (USGS 2009a; Vacarro 2016).

Groundwater levels can fluctuate for a variety of reasons. Groundwater contours are mapped in Figure 10 based on USGS (2009a).

The *vadose zone* is the unsaturated zone between the land surface and the top of the water table. *Depth to water* is the distance between the ground surface and the water table. Time of travel through the vadose zone is dependent on depth to water, the vadose zone material, the amount of recharge, and other factors.

Earthen materials within the vadose zone have different degrees of permeability. *Permeability* is a measurement of infiltration rate, describing the ability of fluids to move through a material. It is intrinsic to the aquifer matrix material. Permeability is applied to both unsaturated and saturated flow and is independent of moisture content.

Moisture movement through the vadose zone is controlled by both material property and percent saturation or moisture content.

Unconfined (water table) aquifers flow generally in accordance with the topography towards rivers, streams, lakes, and springs. The direction of groundwater flow in unconfined aquifers is normally perpendicular to groundwater contours (USGS 2009a). Groundwater flows from the direction of the highest potential energy to the lowest potential energy. The four types of potential energy that influence groundwater flow include gravitational potential, pressure potential, matric potential, and osmotic potential.

The hydraulic conductivity of bedrock units, Columbia River Basalt Group basalts, and basin fill units were estimated from specific capacity data reported on drillers' logs (USGS 2009a). The median lateral hydraulic conductivity of bedrock, basalt, and basin fill units were 3, 3, and 6 feet per day, respectively, throughout the larger study area of the Yakima River Basin (USGS 2009a).

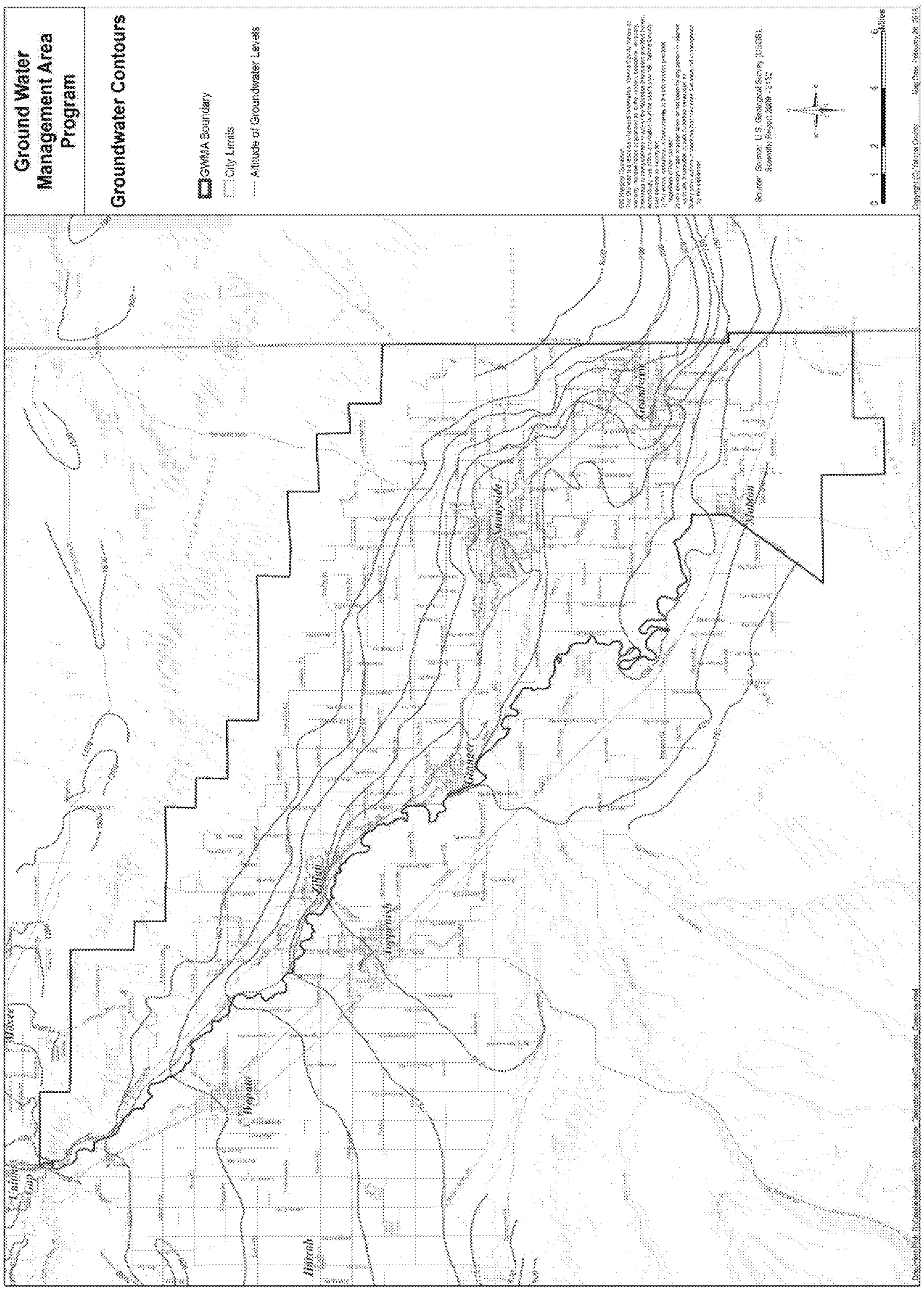

Figure 10 – Groundwater Levels within the GWMA

Topography

The topography within the GWMA is undulating hillsides with elevations from approximately 400 meters (1312 feet) above sea level to the valley floor and river floodplain at an elevation of approximately 230 meters (755 feet) above sea level. Figure 11 shows topography contours.

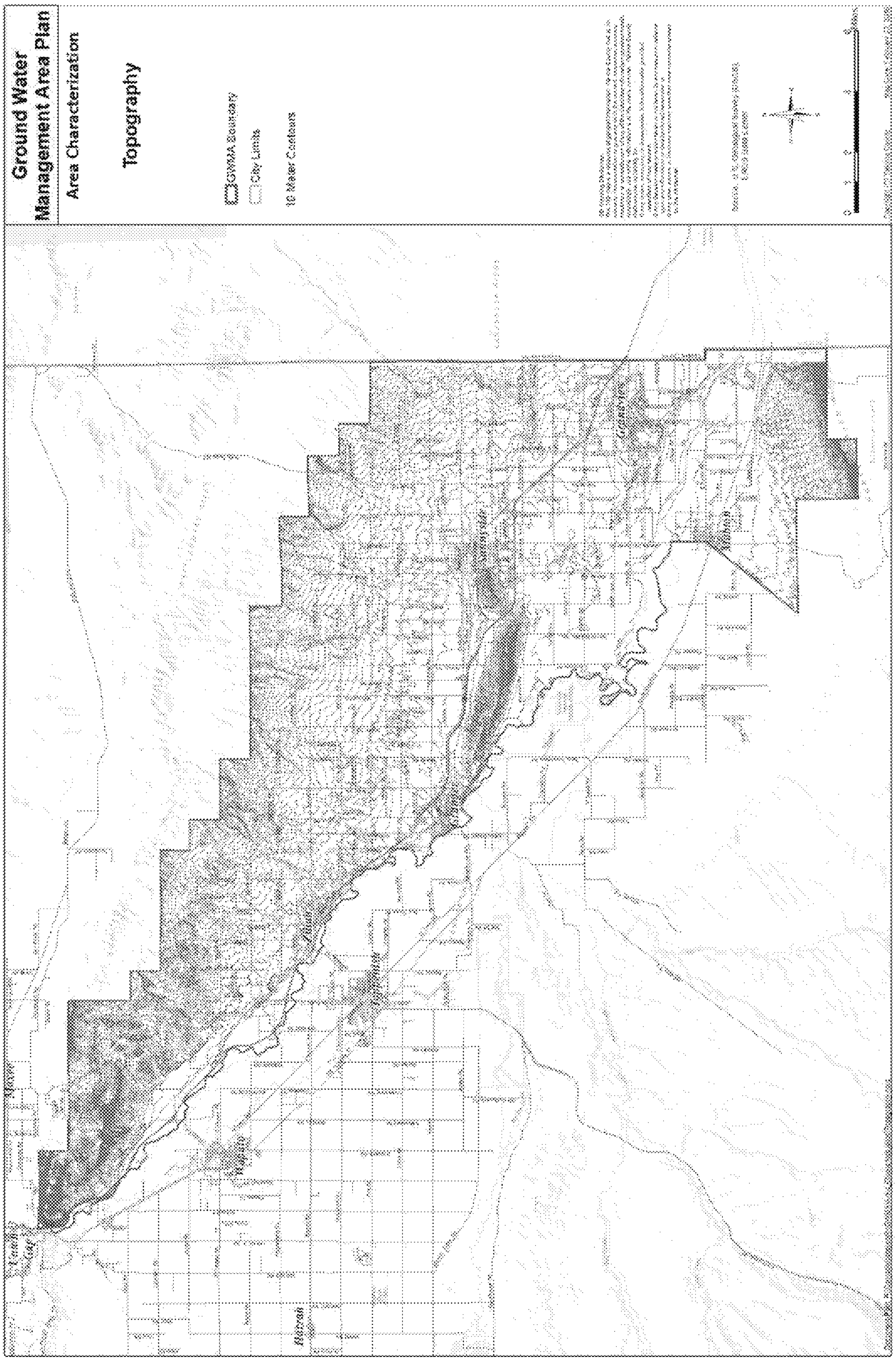

Figure 11 – Ground Surface Contours (Topography) within the GWMA

Depth to Groundwater

Depth to groundwater is typically shallow (0 – 15 feet) at the valley bottom northeast of Granger, north and southeast of Sunnyside, surrounding Grandview, and southeast of Mabton. Depth to groundwater is marginally deeper (15 – 25 feet) in adjacent lands north of Granger, east to areas north of Sunnyside to Grandview, and in the areas surrounding Mabton. Depth to groundwater is deep (25 – 100 feet) roughly in the areas between the Sunnyside Valley Irrigation District (SVID) and Roza Irrigation District (RID) irrigation canals. Depth to groundwater becomes much deeper (100 – 1,000 feet) in areas above the RID irrigation canal. Figure 12 illustrates depth to groundwater and the general directions of groundwater flow within the GWMA, derived from USGS (2009a).

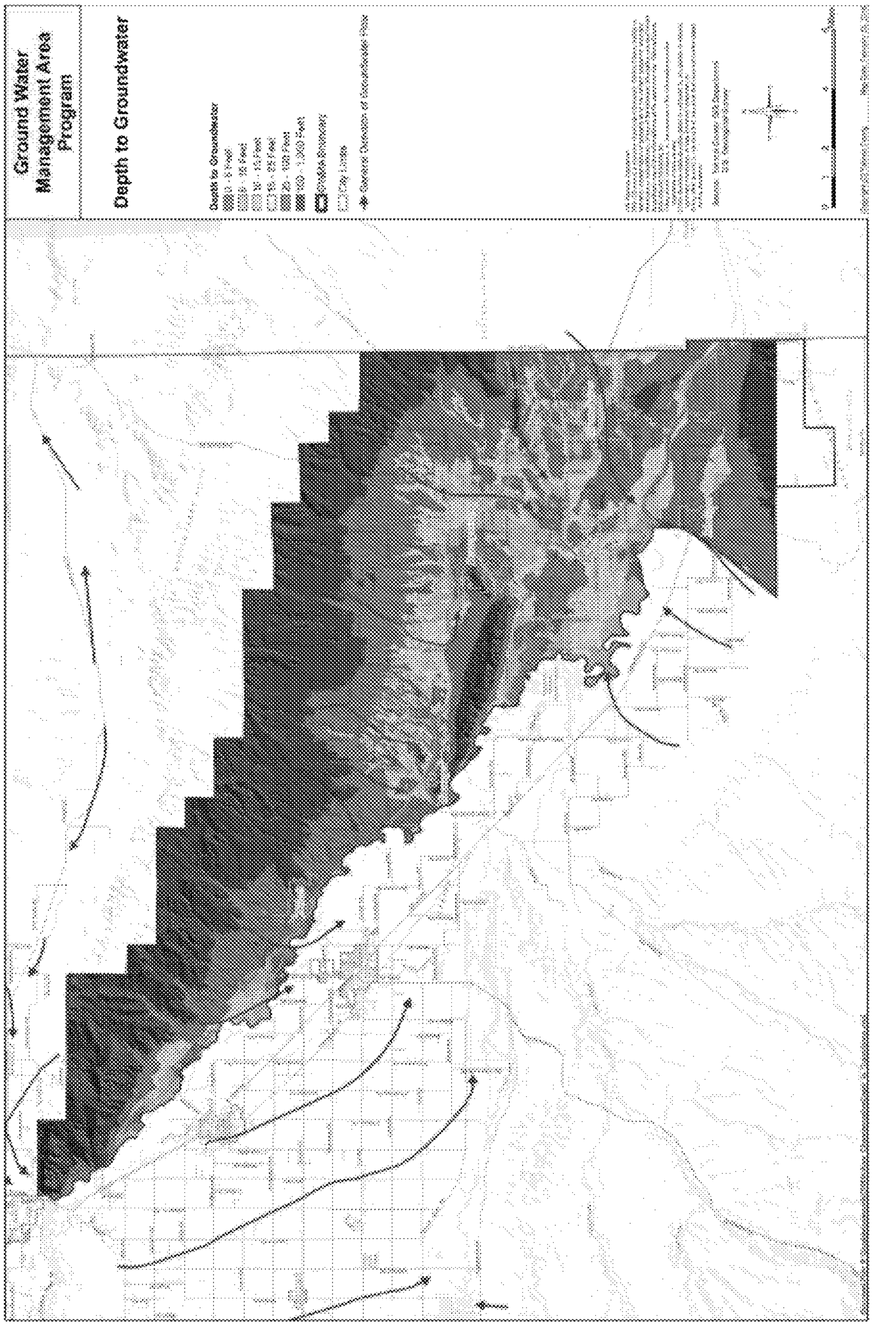

Figure 12 – Depth to Groundwater and Direction of Flow within the GWMA

Soil Types

There are 89 soil types within the GWMA (NRCS, 2018). They differ based on constituency of materials (coarse to very fine sands, loams, clay), values of porosity, specific yield, hydraulic conductivity, and infiltration rate.

Predominant soil types within the GWMA include the following: Scoon silt loam and Burke silt loam (surface roughly 300 meters [1,000 feet] above sea level); Warden fine sandy loam interlineated generally northeast to southwest with Harwood-Burke-Wiehl very stony silt loams and Esquatzel silt loam (surface roughly 250 – 300 meters [800 – 1,000 feet] above sea level); and Esquatzel silt loam, Quincy loamy fine sand, Wanser loamy fine sand, Warden fine sandy loam, and Warden silt loam (roughly within the valley bottom from 200 – 250 meters [650 – 800 feet] above sea level). The hydraulic conductivity of each of these primary soils is presented in Table 4

Table 6 – Primary Soil Hydraulic Conductivity

Soil Type	Hydraulic Conductivity (cu. In / hr)	NRCS rate
Warden silt loam	0.57-1.98	Moderate
Warden fine sandy loam	0.57-1.98	Moderate
Esquatzel silt loam	0.57-1.98	Moderate
Shano silt loam	0.57-1.98	Moderate
Quincy loamy fine sand	5.95-19.98	Rapid
Wanser loamy fine sand	5.95-19.98	Rapid
Harwood Burke-Wiehl silt loam	0.00-0.06	Very slow, impermeable
Burke silt loam	0.00-0.06	Very slow, impermeable
Scoon silt loam	0.00-0.06	Very slow, impermeable

(NRCS, 2018)

All of the 89 soil types within the GWMA are illustrated in Figure 13 and listed by color code in Table 5. Soils were sorted by Yakima County into the hydraulic conductivity categories utilized by the U.S. Department of Agriculture, Natural Resources Conservation Service. These are illustrated in Figure 14.

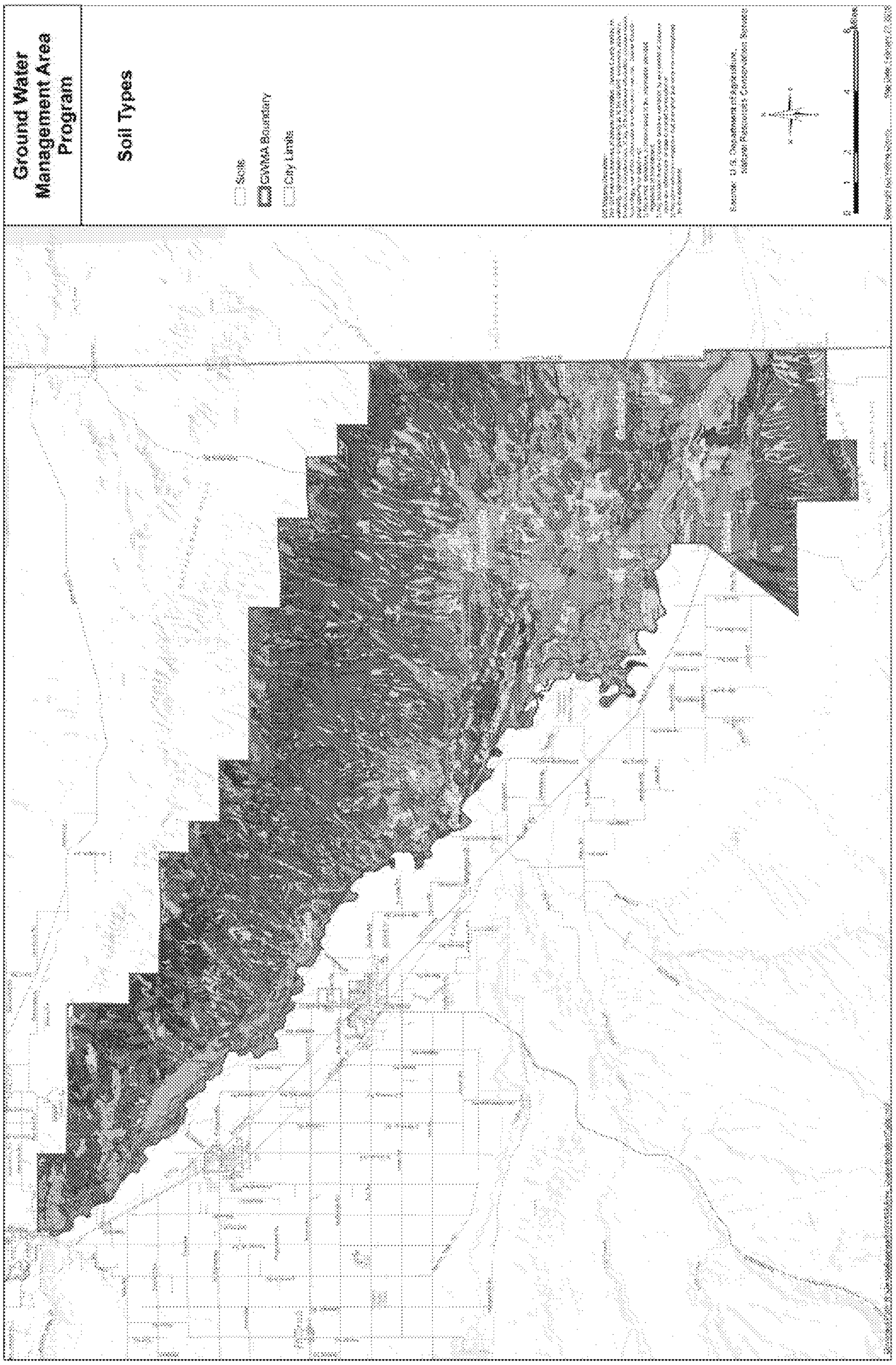

Figure 13 – Soil Types

Table 7 – All Soil Types within the GWMA

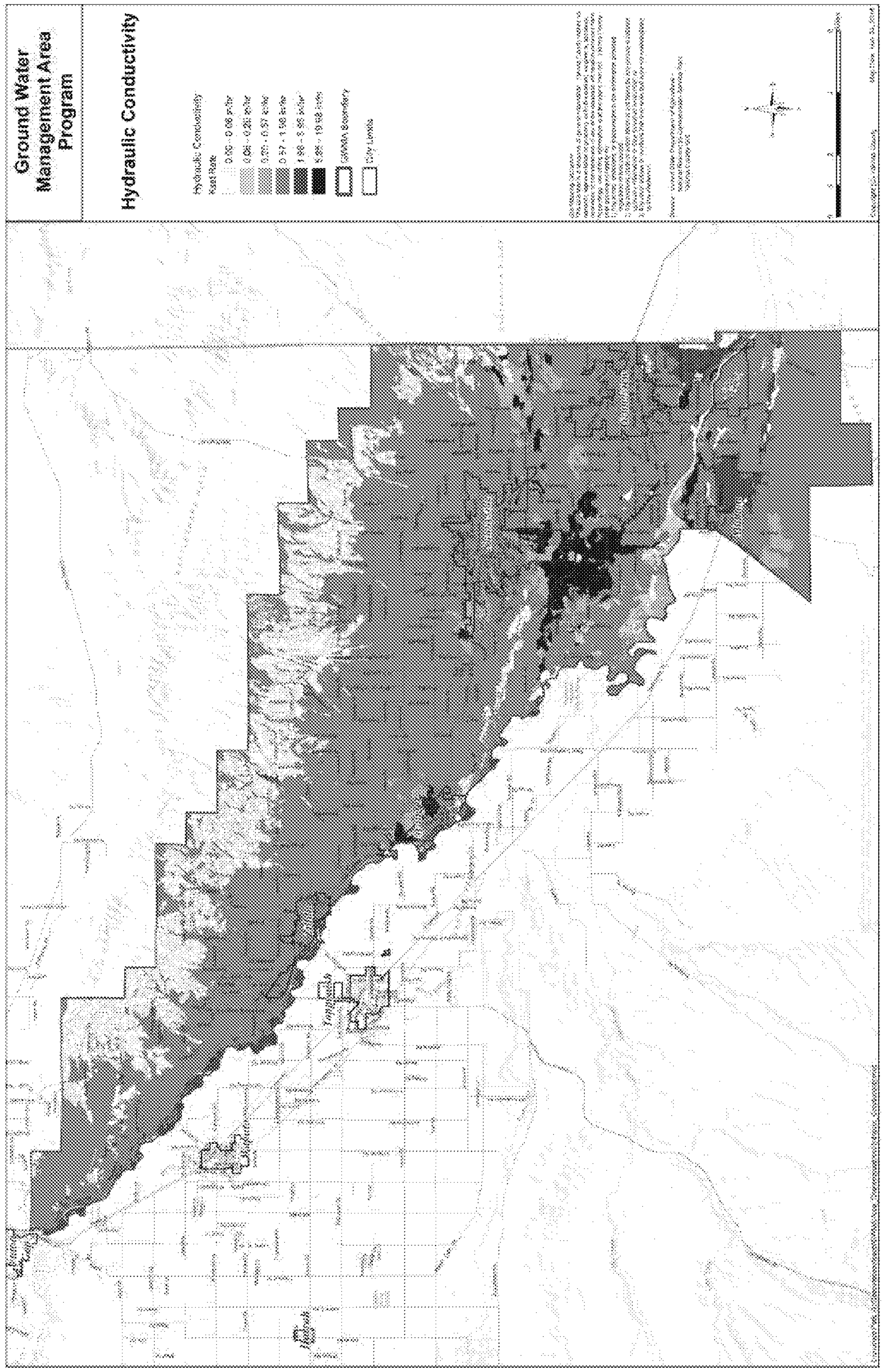

Figure 14 – Hydraulic Conductivity for Soil Types in the GWMA

Climate

The Western Regional Climate Center maintains climate data at three stations within the Lower Yakima Valley at Wapato (Table 6), Sunnyside (Table 7), and Prosser (Table 8). Temperatures have historically ranged from 24 to 90 degrees Fahrenheit over the course of a year (WRCC, 2017). The data does not anticipate or address climate change.

Table 8 – Climate Summary for Wapato, Washington (October 1, 1915 to September 5, 2013)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
Average Max. Temperature (˚F)	38.6	47.4	57.5	66	74.5	81.2	89.2	87.8	79.5	66.5	49.8	39.5	64.8
Average Min. Temperature (˚F)	22.8	27.4	33	39.3	46.9	53.6	59.4	57.3	48.9	38.4	29.9	24.7	40.1
Average Total Precipitation (in.)	1.02	0.68	0.55	0.47	0.53	0.57	0.23	0.28	0.34	0.54	0.98	1.15	7.35
Average Total Snow Fall (in.)	5.8	2.2	0.7	0	0	0	0	0	0	0	1.9	5.4	15.9
Average Snow Depth (in.)	2	1	0	0	0	0	0	0	0	0	0	1	0

(WRCC, 2017)

Table 9 – Climate Summary for Sunnyside, Washington (September 14, 1894 to January 5, 2014)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
Average Max. Temperature (°F)	39	47	58	67	75	82	90	89	80	67	51	40	65.3
Average Min. Temperature (°F)	23	27	32	38	45	51	55	53	46	37	30	25	38.4
Average Total Precipitation (in.)	0.9	0.6	0.5	0.5	0.5	0.5	0.2	0.3	0.4	0.6	0.9	0.9	6.8
Average Total Snow Fall (in.)	4.5	1.8	0.2	0	0	0	0	0	0	0	1.8	4	12.4
Average Snow Depth (in.)						No	Data						

(WRCC, 2017)

Table 10 – Climate Summary for Prosser, Washington (July 1, 1925 to January 4, 2015)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual total
Average Max. Temperature (°F)	38	46	56	65	73	80	89	87	78	65	49	40	63.9
Average Min. Temperature (°F)	24	28	33	38	45	50	55	53	47	39	31	26	38.9
Average Total Precipitation (in.)	1.1	0.7	0.6	0.6	0.6	0.7	0.2	0.3	0.4	0.7	1	1.2	7.95
Average Total Snow Fall (in.)	2.6	1.2	0.1	0	0	0	0	0	0	0	0.9	2.3	7.2
Average Snow Depth (in.)	1	0	0	0	0	0	0	0	0	0	0	0	0

(WRCC, 2017)

Land and Water Use

This section focuses on the current and historical land uses, crops grown, types of fertilizers used, water sources, and irrigation methods used within the Lower Yakima Valley GWMA.

Land Use

Land use within the GWMA is subject to the Yakima County Code. Most of the land within the GWMA is within the code's designated agricultural zone. Figure 15 illustrates Yakima County zoning districts within the GWMA.

Agriculture is the primary economic and land use activity in the area. Approximately 70 to 80 percent of the land is used for agriculture (Ecology, 2010). Agricultural production on the 464,000 irrigated acres within the Yakima River Basin is estimated to be worth over $2 billion annually (apples, $1 billion; dairy, $900 million; hops, $500 million).

In 2007, the total market value of Yakima County crops sold was over $1.2 billion, and the average market value per farm was $340,058. In 2012, the total market value of Yakima County crops sold was over $1.6 billion and the average market value per farm was $523,548 (Yakima Valley Trends 2018a).

In 2007, the value of Yakima County milk production was $325 million. In 2012, the value of Yakima County milk production was $439 million (Yakima Valley Trends 2018b).

In 2007, Yakima County's net cash farm income was over $372 million and its net cash farm income per farm was $105,100. In 2012, its net cash farm income was over $321 million and its net cash farm income per farm was $102,356 (Yakima Valley Trends 2018c).

In 2007, the 68,087 acres of fruit trees in Yakima County were valued at almost $750 million. In 2012, the 62,415 acres of fruit trees in the county were valued at over $935 million (Yakima Valley Trends 2018d).

Most cropland in the area is irrigated. Major commodities grown in the valley include apples, pears, cherries, peaches, vegetables, hay, mint, and hops. In 2002, Yakima County ranked first statewide for apple, milk, hop, and grape production and first nationally for apple and hop production. Concentrated animal feeding operations (CAFOs) greatly expanded starting in the late 1980s (Drennan, 2013), and the number of dairy cows in Yakima County reached 37 percent of Washington State's cattle population in 2008 (Yakima Valley Trends 2018e). Also, animal feeding operations operate at various sizes, from very small home lots to large commercial feedlots. The CAFOs are concentrated in the lower parts of the valley in and around the cities of Sunnyside, Grandview, Mabton, and Granger. Some are located in more distant parts of the valley and on the Yakama Indian Reservation.

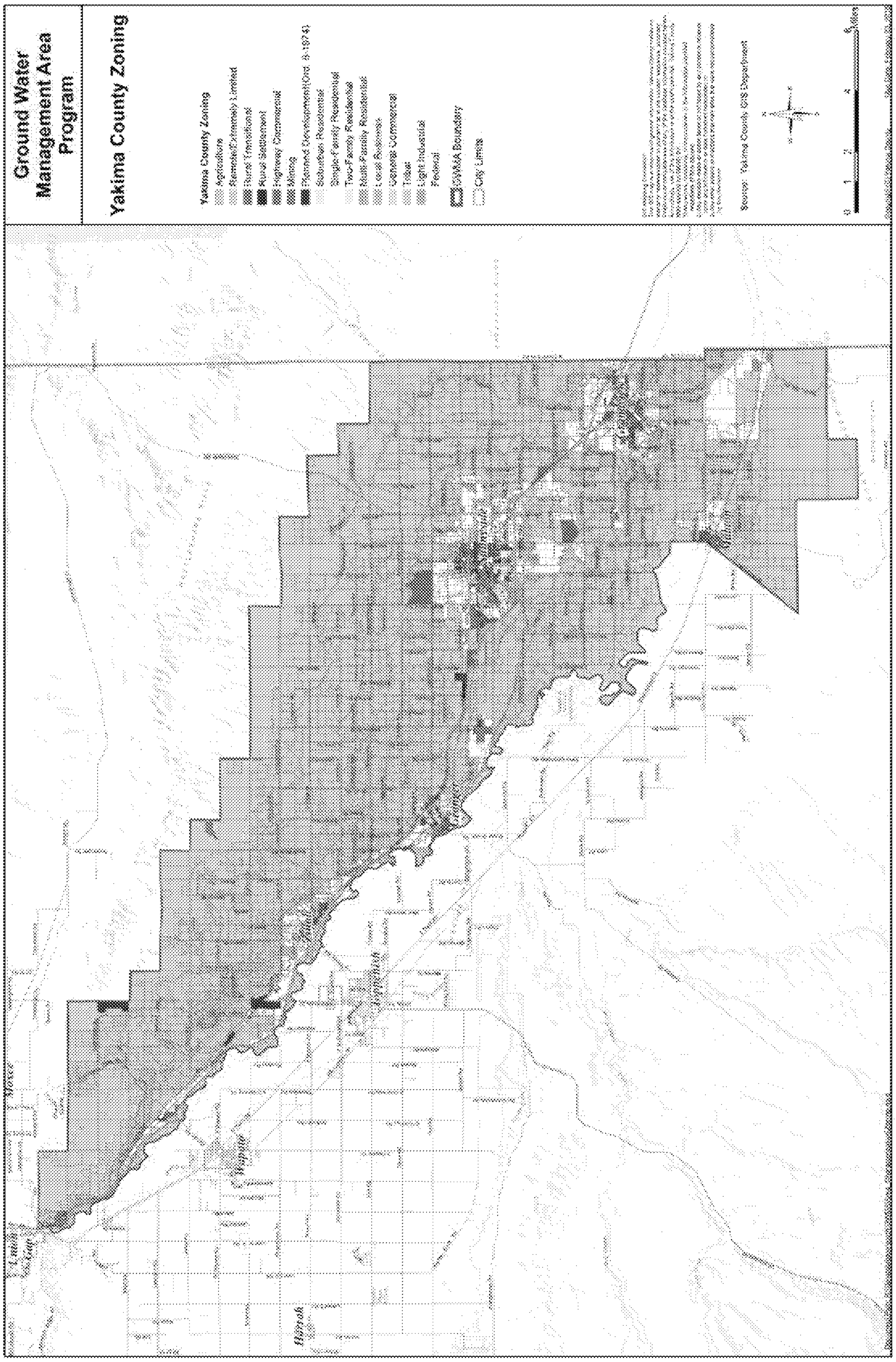

Figure 15 – Yakima County Zoning Within GWMA

Farming has been a historic land use practice in the Lower Yakima Valley since the mid-1800s. The Yakima Valley Museum maintains a collection of historical photographs (figure 16).

European-style agriculture began in the Yakima River Basin in the mid-nineteenth century, with the arrival of Catholic missionaries. They established a mission in 1852 on Atanum (now Ahtanum) Creek, using irrigation on a small scale. Miners and cattlemen immigrated to the basin in the 1850s and 1860s. In 1859, Ben Snipes first drove cattle through the Yakima Valley. Five years later, he returned and established the Snipes and Allen Company, grazing 40,000 – 50,000 head of cattle in the Lower Yakima Valley. By the 1880s, about 200,000 cattle, 350,000 sheep, and 125,000 horses grazed in the Yakima Valley. By the mid-1860s, irrigation of the valley bottoms began. Private companies built canal systems between 1880 and 1904 and delivered water for the irrigation of large areas. Outlying areas were used extensively for raising livestock. The Northern Pacific Railway was constructed through the Yakima Valley, reaching Yakima in December 1884 and Seattle in 1896, further facilitating the development of irrigated agriculture through transport of agricultural goods to markets. Statehood in 1889 assisted Lower Yakima Valley agricultural growth, with Yakima contending for state capital. When the National Reclamation Act passed in 1902, about 85,000 acres were under irrigation in the Yakima Valley, mostly by surface water (Boening 1919).

By 1901, farming had largely replaced livestock ranching in the easily irrigated acres of the valley. A state survey of that year reported the following crops grown in the Yakima Valley: apples, pears, prunes, plums, cherries, apricots, peaches, and grapes; alfalfa, corn, wheat, barley, oats, rye, flax, broom corn, and other grasses, including brome, orchard, tall meadow fescue, timothy, red top, and clover; melons, potatoes, garden vegetables, hops, and sugar beets (Jensen and Olshausen 1901).

Crops

The Yakima Valley Museum maintains a collection of historical photographs that indicate significant production of hops, primarily in the Moxee and North Yakima area.

In the Lower Valley, early agriculture primarily involved the production of hay, but early crops also included hops (Jensen and Olshausen 1901). Orchards were planted in the Sunnyside area by 1908. Between 1905 and 1912 the Lower Yakima Valley towns of Sunnyside, Mabton, Toppenish, Wapato, Grandview, Granger, and Zillah were all incorporated.

A 1917 survey showed the following crops produced in the Yakima Valley: strawberries, cherries, prunes, apples, peaches, pears, apricots, grapes, cantaloupes, watermelons, onions, turnips, green corn, carrots, rutabagas, cabbage, asparagus, tomatoes, green peppers, squash, pumpkins, beans, potatoes, hops, sugar beets, alfalfa hay, wheat, oats, and barley (Drennan, 2013).

By the early 1920s, field crops such as potatoes, onions, and corn were primarily watered by flood irrigation, either through total inundation or rill irrigation.

Tree fruits had become successful export products by the 1930s.

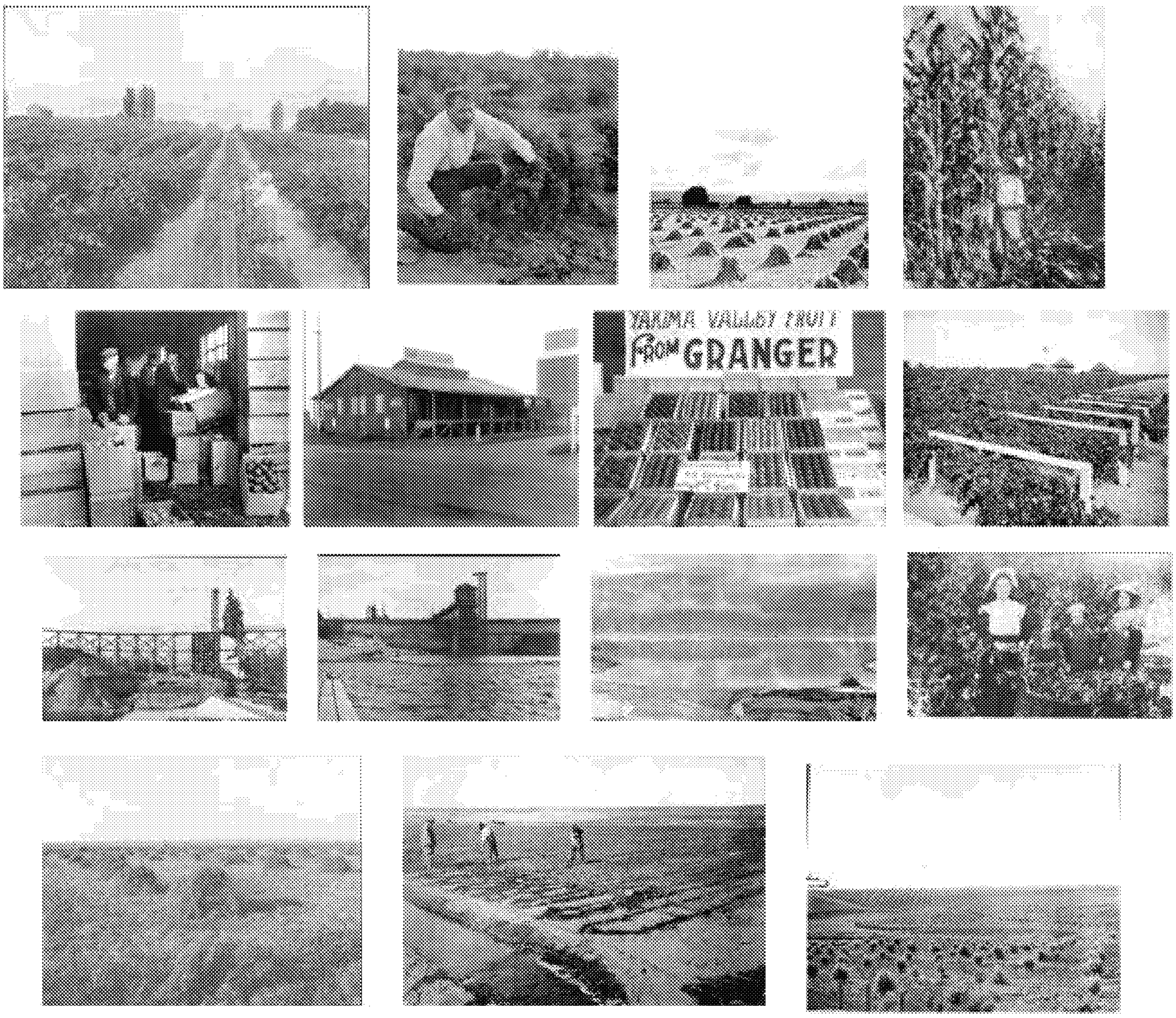

Figure 16 – Historical photographs of agriculture in Yakima County.

Historical photographs courtesy of the Yakima Valley Museum. For further study, see [Yakima Memory website]() **at: http://www.yakimamemory.org/.**

The Federal Reclamation Act of 1902 and Washington State's Yakima Federal Reclamation Act of 1905 authorized construction of water delivery facilities to irrigate about 500,000 acres of land within the Yakima River Basin, including those within the Lower Yakima Valley. Six dams and five reservoirs were constructed as part of the Yakima Project.

These federal reservoirs provide storage to meet water requirements of the major irrigation districts during the period of the year called "storage control," when the natural streamflow from unregulated streams can no longer meet demands.

Farm sizes were relatively small during the first half of the twentieth century. There were 6,351 farms in Yakima County, making up 600,106 acres of farmland, in 1925 (Drennan, 2013).

> Farmers often produced their own livestock feed on farm, and maintained soil fertility through crop rotations and the retention of manure and crop residues on-farm. Weeds, insects, and plant diseases were controlled largely through mechanical practices, crop rotation, and the use of natural predators. During this time the conversion from horse-powered farming to the widespread use of tractors was taking place. . . . This spread of mechanization made it possible for farmers to use agricultural practices like intensive inversion-based tillage that remove all cover from the soil and use large amounts of fuel. (Drennan, 2013)

The National Map Company's 1930 map entitled *Latest Official Survey of Washington* shows the route of two railroads then running through the GWMA area, used to transport agricultural goods to market (Presby Museum; Goldendale, Washington) (See Figure 17). The number of railroad depots indicates the abundance of agricultural commodity sent to market. The Union Pacific route stopped in Grandview, Forsell, Waneta, Midvale, Morris, Emerald, Bain, Noride, Granger, Blaine Acres, Dalton, Boone, Pam, Zillah, Buena, Flint, Sawyer, Dunbro, and Parker en route to Union Gap and Yakima. The Northern Pacific route stopped at Grandview, Lichty, Sunnyside, Outlook, Nass, Sinto, Granger, Boone, Gilliland, Cenauer, Zillah, Keck, Cutler, Buena, Sawyer, Donald, Mellis, and Parker en route to Union Gap and Yakima.

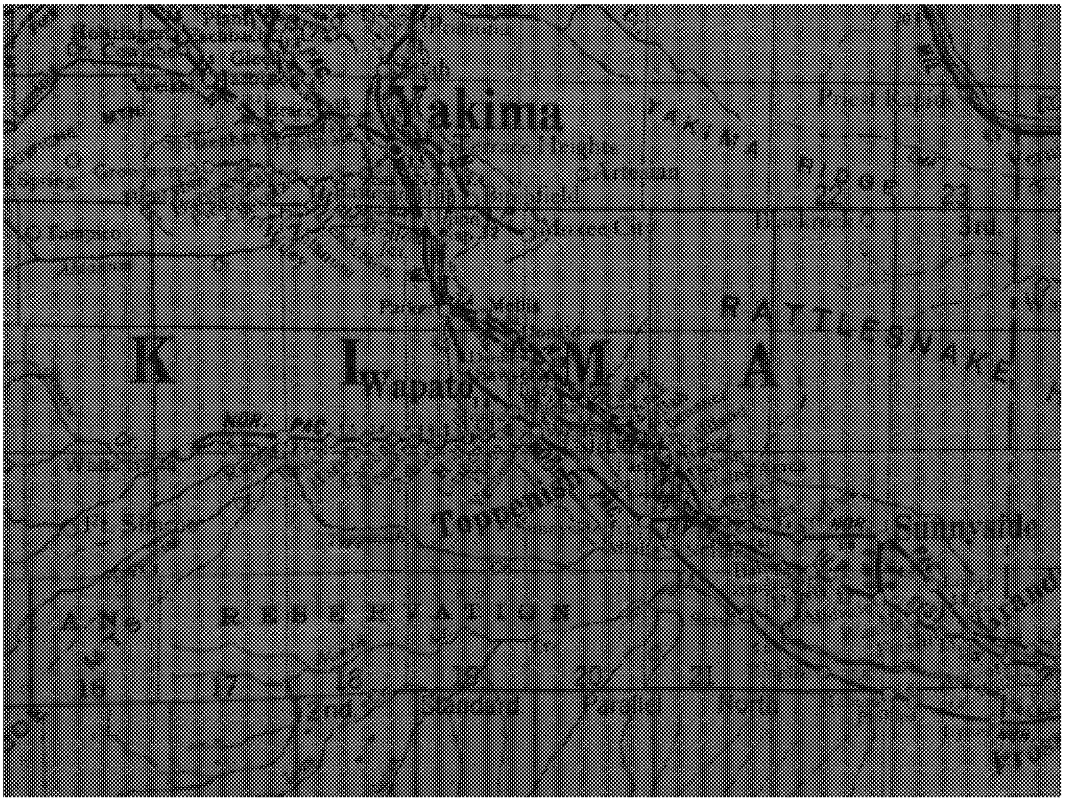

Figure 17 – The National Map Company's 1930 map entitled Latest Official Survey of Washington.

The number of farms and the area being farmed throughout Yakima County stabilized during the 1940s. In the 1950s, the total number of farms began to decrease while the total amount of land being farmed increased, due primarily to the growth of land used as pasture. Between the 1960s and early 2000s, the total amount of land being farmed in Yakima County remained relatively constant.

Table 9 displays the number of acres historically farmed in Yakima County organized by crop category. Additional information on specific field crops is presented in Table 10. Data were collected by the U.S. Department of Commerce (USDOC), Bureau of the Census and published in the United States Census of Agriculture (USDOC Agriculture). The census information does not segregate data into geographic subdivisions of Yakima County. Nevertheless, the information does reflect trends in agricultural practices within the GWMA, because the GWMA constitutes a major portion of the county's agricultural economy(Drennan, 2013).

Table 11 – Historical summary of crop types in Yakima County by number of acres farmed (x1000)

Crop Type	1935	1959	1982	2007
Apples, cherries, peaches, pears, plums, prunes and grapes	52.0	83.0	89.0	95.0
Corn, wheat, oats, barley, rye and triticale	55.0	94.0	101.0	83.0
Hay, forage, haylage and silage (including small grains cut for hay, wild hay, sorghum cut for silage or greenchop)	71.0	49.0	32.0	52.0
Potatoes, sugar beets, mint, hops, dill and dried herbs	18.0	48.0	36.0	44.0
Vegetables (including snap and string beans, cabbages, sweet corn, tomatoes and watermelons)	6.0	23.0	20.0	10.0
Field seeds and grass seeds	0.0	10.0	0.5	1.0
Legumes (excluding cover crops)	0.1	0.3	3.3	0.5
Berries	0.0	0.1	0.0	0.1

(Drennan, 2013)

Table 12 – Historical summary of specific field crops in Yakima County by number of acres farmed (x1000)

Crop Type	1935	1959	1982	2007
Sweet Corn	1.0	9.0	5.0	2.0
Asparagus	2.0	10.0	10.0	2.5
Hops	4.0	19.0	19.0	19.0
Mint	0.0	10.0	25.0	10.0
Sugar Beets	1.0	19.0	8.0	2.0
Alfalfa	65	40	30	41
Alfalfa seed	0.295	10	3	1
Wheat	20	31	60	21
Corn for grain and silage	8	43	21	42
Barley	7	17	17	0.5

(Drennan, 2013)

Trends in U.S. farming began to shift after World War II from mixed crop and livestock operations to specialized monocultures (table 11). Livestock were raised separately on feedlots. Crop rotation decreased. Livestock manure, commercial fertilizer, and pesticides were readily available. Yields of corn, wheat, and rice increased during the latter half of the twentieth century due to large-scale mechanization of tilling, planting, and harvesting; improved plant varieties; development of irrigation infrastructure; availability of low cost fertilizers and pesticides; and favorable commodity prices. Economies of scale led farm sizes to increase. By 2007, there were 3,540 farms totaling 1,649,281 acres in Yakima County (Drennan, 2013).

Table 13 – Historical summary of livestock in Yakima County

Animal	1935	1959	1982	2007
Cattle and calves	51	135	152	213
Dairy Cows	20	18	19	90
Chickens	220	240	520	300
Sheep	100	75	25	10

Number of Livestock (x1000)
(Drennan, 2013)

The Washington State Department of Agriculture maintains an annual inventory of crops grown on particular properties. Figure 18 illustrates the variety and location of crops grown within the GWMA in 2015.

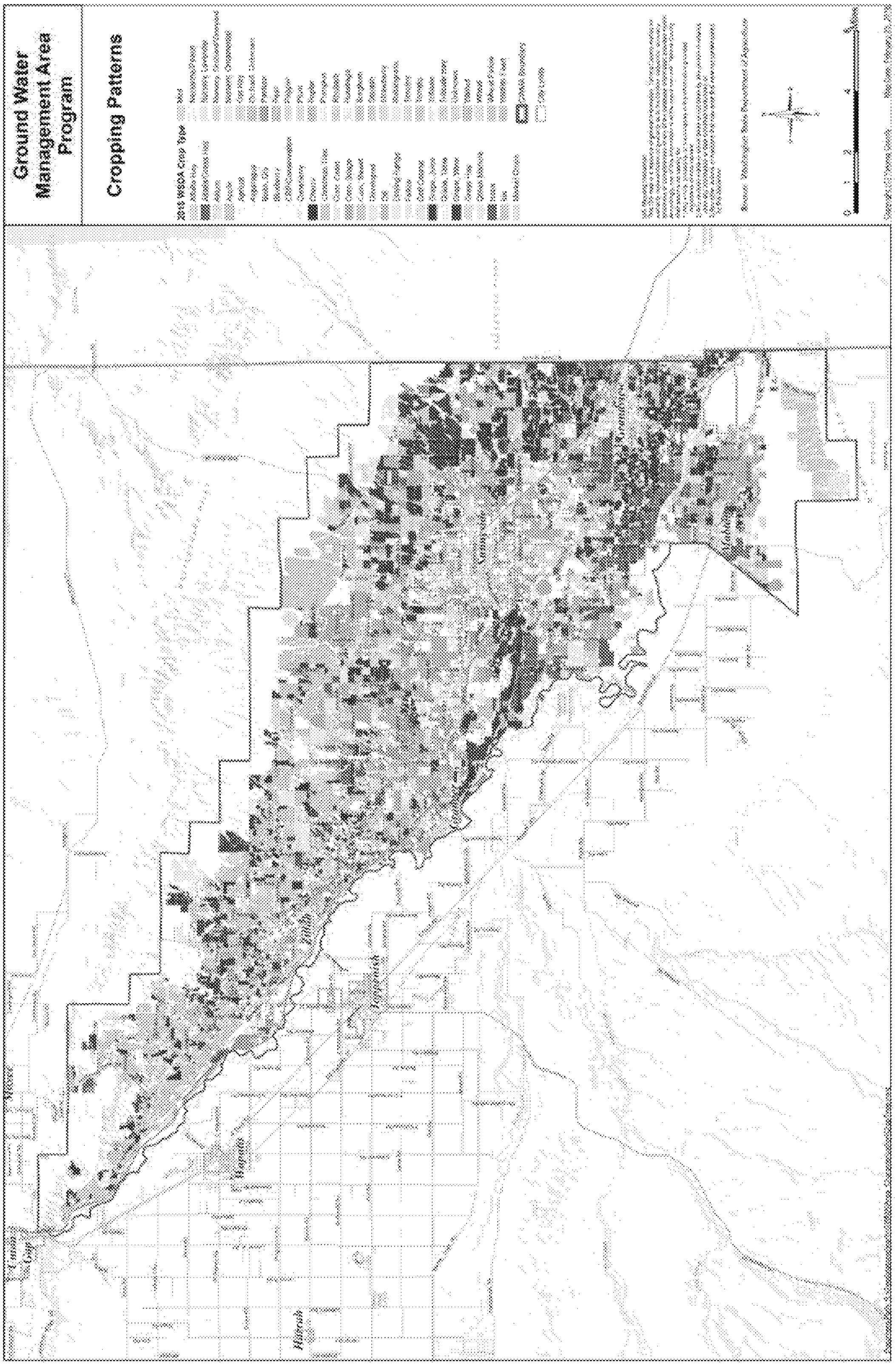

Figure 18 – Locations of Crops Grown within the GWMA (2015)

Table 14 – Top 15 crops in the GWMA

Crop Type	Acreage
Apple	17,333
Corn (silage)	16,778
Triticale	10,780
Grape (juice)	10,257
Alfalfa	7,989
Pasture	6,731
Cherry	6,336
Hops	5,961
Grape (wine)	5,126
Pear	3,331
Mint	1,418
Wheat	1,283
Corn (grain)	1,166
Asparagus	854
Peach/Nectarine	843

(WSDA 2018)

Table 14 describes the top most recent account of crops grown within the GWMA. The acreage totals in the table do not account for multiple cropping in a single year. According to WSDA (2018), double cropping occurred on 10,780 acres of triticale, primarily on the same ground as corn silage after the corn silage had been harvested.

Fertilizers

In 1954, fertilizers were applied to 136,553 farmed acres within Yakima County. In 1964, the number of acres fertilized increased to 203,062 acres. The fertilized area within Yakima County remained fairly constant through 2007.

The manure-fertilized area in 2002 was 28,152 acres. In 2007, the area fertilized by manure was calculated at 27,742 acres, which is approximately 14 percent of the total fertilized acres within the county (Drennan, 2013; USDOC 2010).

The USDOC Agricultural Census also collected information between 1954 and 1974 about the number of acres within Yakima County fertilized with commercial fertilizer. The maximum number occurred in 1970, when approximately 110,000 acres received commercial fertilizer (Drennan, 2013).

The use of commercial fertilizers began to increase between 1900 and 1944. After World War I, the use of pesticides increased as well. WSDA interviewed commodity-specific experts to obtain a typical range of use rates for manure, compost, and commercial fertilizer for each of the GWMA's 15 top commodities (WSDA 2018); they found that 19 percent of total GWMA irrigated acreage was fertilized by manure, 74 percent by commercial fertilizer, and 8 percent by compost.

Water Use

The Lower Yakima Valley south of Union Gap is semi-arid, with a mean annual precipitation of 6.8 inches. Precipitation and snowpack in the Cascade Mountains, along with groundwater, provide the source water and natural storage capacity for the Yakima River. The Yakima River is the primary source of irrigation water. Diversions from the river are managed by the U.S. Bureau of Reclamation (USBR, 2018).

Irrigation water can also be drawn from wells pursuant to individual water rights recognized by the Washington State Department of Ecology (Ecology). Under the Washington State groundwater code (RCW 90.44.050), prospective groundwater users must obtain authorization of a water right for irrigation (other than that exempted by the statute). Post-1945 well-drilling technologies, legal rulings, and the onset of a multi-year dry period beginning in 1977 stimulated the drilling of numerous irrigation wells. Population growth in the basin has also resulted in increased drilling of shallow domestic wells in addition to deeper public supply wells. There are now more than 20,000 wells in the basin, of which more than 70 percent are shallow (less than 250 feet). Ecology's online water rights database indicates that there are 2,874 active groundwater rights associated with wells in the Yakima Basin. Some of these are emergency drought wells. They collectively can withdraw about 529,231 acre-feet during dry years. The irrigation rights are for the irrigation of about 129,570 acres. There are about 16,600 groundwater claims in the basin, for approximately 270,000 acre-feet of groundwater (USGS 2011b).

The three largest irrigation providers in the lower valley are the Wapato Irrigation Project, Sunnyside Valley Irrigation District (SVID), and the Roza Irrigation District (RID). Wapato Irrigation Project serves irrigators within the Yakama Indian Reservation and is managed by the U.S. Bureau of Indian Affairs on behalf of the USBR. In 2012, SVID served 94,614 acres. SVID diverts its water near Parker into a 60-mile canal running generally northwest to southeast through the GWMA, in essentially the same direction of groundwater flow. RID serves 72,491 acres, but the higher elevations of the district are not within the GWMA. Those within the GWMA are on the north slopes of the valley (Drennan, 2013). RID diverts its water from the Yakima River upstream of the city of Selah into a 94.8-mile canal.

Diverse crops are grown in both the SVID and RID service areas. Generally, forage crops dominate the SVID and tree fruits dominate the RID. Both canals end, returning tail water to the Yakima River, near Benton City. From the canals, water travels 709 miles of laterals to over 5,300 locations. Diversions usually begin in March to prime the canal system and cease in mid-October. On-farm deliveries typically begin in early April. Figure 19 shows the service areas of SVID and RID within the GWMA.

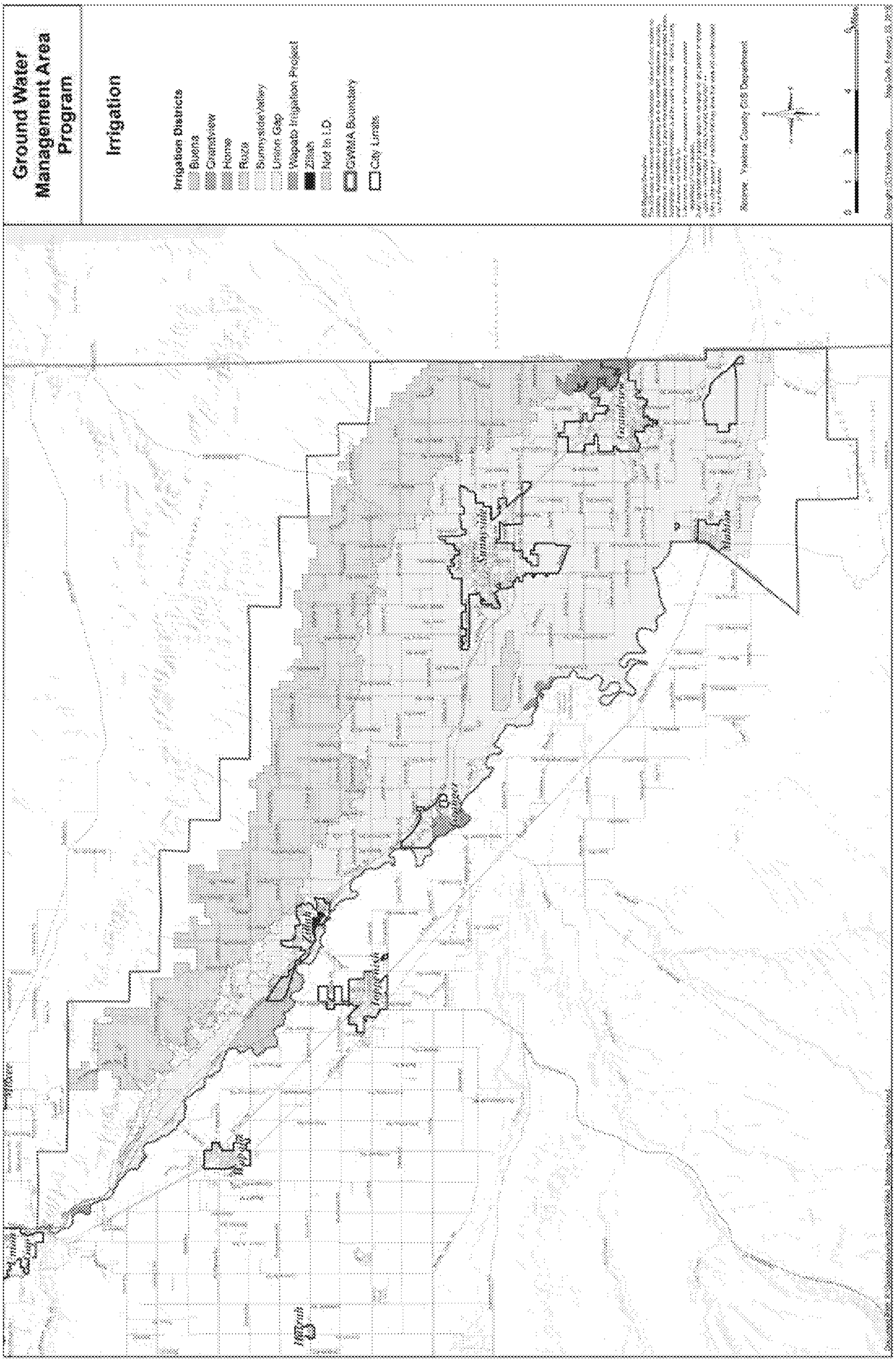

Figure 19 – Sunnyside Valley and Roza Irrigation Districts within the GWMA

Irrigation Methods

Irrigation in the Yakima River Basin is accomplished using one of three methods: rill, sprinkler, or drip. Rill (or gravity) irrigation is the oldest and simplest form in use, consisting of an open channel (head ditch) that delivers water to the high point of a field. Water flows out of the head ditch and into small furrows cut into the field between each crop row. Water exits the furrows at the low point of the field and is collected in a second open channel (tail water ditch). This tail water may be reused by pumping it back to the head ditch multiple times or transported by gravity flow to other farmed land. The tail water may then be routed to a drain that feeds into the regional drainage network. On many rill-irrigated fields, the open head ditch has been replaced with PVC pipe. Manually operated spigots or sliding gates direct irrigation water into the furrows.

A variety of sprinkler systems are used throughout the Yakima River Basin, and each system varies in its efficiency of delivering water. Portable handline, portable solid set, wheel lines, and big guns are examples of simple systems to operate, but they also require manual labor to move from place to place in a field. Fixed in-ground solid set, center pivots, and linears are automated systems. They are more expensive to install and more complex to operate, but they provide a more even coverage and give the farmer greater control over the irrigation process. These systems can be fully automated, enabling the farmer to irrigate a large area with less labor. Sprinklers can be used for sunburn and frost control on fruit, but this can also lead to overapplication of water. Adding this extra water could drive nutrients into groundwater, depending on the amount of water applied and the amount of nutrients in the soil.

Drip irrigation employs plastic lines with small openings to deliver water directly to the base of the plant. The drip lines may be installed above or below the soil. A properly operating drip irrigation system enables maximum use of the farm's allotment of water; very little water is lost to evaporation, no tail water is generated, and virtually no water is lost to the groundwater system. Drip systems are used primarily to deliver water, but they can also be used to deliver nutrients and pesticides. (USGS 2004).

Irrigation efficiency varies depending upon the method. Rill irrigation methods are approximately 50 percent efficient, sprinkler irrigation is approximately 75 percent efficient, and center pivot irrigation is approximately 90 percent efficient in delivering water to the crop. Typically, efficient irrigation systems also provide uniform coverage. The most sophisticated systems use feedback from soil-moisture probes and GPS to cycle the irrigation system off and on (USGS 2004).

Sprinkler irrigation systems increased in the Roza and Sunnyside Irrigation Districts between 2005 and 2012, the years for which records are available. Rill irrigation systems have decreased. Sprinkler irrigation in those districts is somewhat lower than it is statewide. Low-flow drip irrigation had increased to 26.16 percent of the acreage in the Roza District by 2010 (Drennan, 2013).

Demographics

This section focuses on the characteristics of the people who live in the GWMA, including population, income, education, household and family size, ethnicity, and language.

Population

Yakima County is the second-largest county in Washington by area, occupying 4,311 square miles, and the eighth-largest county in the state by population, with 244,654 people (USDOC 2010). Twenty-three percent of the Yakima County population (56,210 people) live within the GWMA, with approximately 63 percent residing in cities (Table 13) (USDOC 2010).

Table 15 – Population of Cities within the GWMA

City	Population
Sunnyside	15,858
Grandview	10,862
Granger	3,246
Zillah	2,964
Mabton	2,286

(USDOC 2010)

Approximately 36 percent of the population (19,952 people) reside in unincorporated rural areas that are not served by public water or sewer. These residents typically rely on private domestic wells for their drinking water and on-site sewage systems (OSS, or septic system) to dispose of their waste (USDOC 2010).

In the GWMA, economics and livelihood play a critical role in the decision to live in a rural area instead of an urban one. Affordable housing is a draw to rural areas, and so is the proximity to agricultural employment. Farmers, for example, usually live on or near the acreage they farm.

However, other factors are at play in addition to affordable housing and agriculture. In recent decades in Yakima County, large-tract farmsteads have been parceled and sold in smaller pieces over time. The smaller parcels are not large enough to make a living at traditional farming, but they do offer part-time farming opportunities for people already employed and seeking a country lifestyle. This is the chief characteristic of rural living in Yakima County and the GWMA (Yakima County 2017). The desire for a country environment in part accounts for the growing number of rural GWMA households, ranging in property size from 0.5 to 10 acres, with distances from urban areas that preclude them from receiving municipal water or sewer services.

Income

Yakima County's median household income of $43,506 is below Washington State's median income of $59,478. The county's per capita income of $19,433 is also below Washington State's per capita income of $30,742 (USDOC 2013).

Education

Educational attainment is a good indicator of the earnings potential of an individual. It also reveals the quality of the labor force. The U.S. Census (five-year American community survey over the years 2009 to 2013) shows that in Yakima County, 16.8 percent of all persons aged 25 years and over have less than a ninth grade education, while 15.5 percent of the same age group had four or more years of college education. In comparison, at the state level, 4 percent have less than a ninth grade education and 31.6 percent have four or more years of college. Census data for 18- to 24-year-olds indicates that 31.2 percent of Yakima County residents have less than a high school diploma, compared to 16.4 percent for the state (Yakima County 2017).

Households and Families

The average household size in the GWMA ranges from 3.36 to 3.98 people per household, larger than in Yakima County (3.02 people) and Washington State (2.54 people). Average family size in the GWMA ranges from 3.72 to 4.38 people — again, larger than the average county family size (3.53) or the state (3.11). In the GWMA, 80.2 percent of all households are comprised of families compared to 73.0 percent for the county and 64.5 percent for the state (USDOC 2013).

Ethnicity

The GWMA has a higher concentration of individuals whose ethnicity is Hispanic or Latino compared to Yakima County, Washington State, or the nation, and a lower concentration of American Indian, Alaska natives, and African Americans (USDOC 2013).

The Yakima Indian Reservation borders the western boundary of the GWMA. Although the reservation is not within the GWMA boundary, tribal representatives participated in the GWAC.

Language

In Yakima County, 39.6 percent of the population over age 5 speaks a language other than English at home (predominantly Spanish). Additionally, 18.6 percent speak English less than "very well," indicating that the other 21.0 percent are bilingual. In the GWMA, 60.6 percent of the population over age 5 speaks a language other than English at home, and 24 percent speak English less than "very well," indicating that the other 36.4 percent are bilingual. (USDOC 2013)

GWAC Initiatives

Education and Public Outreach

The education and public outreach is an essential component for a successful program since it is an integral part of each objective. Meeting objectives at all levels entails good communication with affected parties. And since success relies heavily on residents within the Lower Yakima Valley GWMA changing their habits, education and public outreach is the center point of all initiatives.

The GWAC determined it was a priority to inform residents about the health risks from drinking water with elevated concentrations of nitrate, especially for vulnerable individuals.

The goal of the education and public outreach efforts was to inform and educate the public about nitrate groundwater contamination and its health and environmental impacts, promote GWMA activities, and encourage engagement in the process by the community and key stakeholders.

The primary initiatives were to:

- Promote the protection of groundwater quality.
- Provide a forum for stakeholders to discuss nitrate reduction methods and improvement of groundwater quality.
- Establish a GWMA website to serve as the central clearinghouse for all GWMA related activities.
- And to educate residents on health risks, treatment programs, and testing of private domestic wells.

The detailed plan developed for education and public outreach is contained in appendix E. The educational materials produced are contained in Volume III – Accomplishments. These materials were often produced in both English and Spanish to accommodate as many community members as possible.

Many of the education and public outreach efforts included a survey component to provide direct and immediate feedback, which allowed efforts to be refined to be as effective as possible. It was noted that personalized letters based on individual well water quality results were the most effective at informing residents.

Nitrate Treatment Pilot Program

One of the highest priorities was to provide outreach to residents that were drinking water with elevated concentrations of nitrate and to provide free water treatment systems. This effort was led by Yakima County, who partnered with the Departments of Health, Ecology, EPA, the Yakima Health District, and the Yakama Nation.

An intensive bilingual outreach effort was implemented distributing 7,641 English/Spanish packets to every household on a private well via either mail or hand delivery. Public meetings were held with an interpreter, bilingual radio and TV spots were aired; door-to-door intensive Spanish-language outreach conducted, and a toll-free bilingual hot line was established.

Approximately between 700 and 1,000 homes in the GWMA were supplied by water wells with nitrates in excess of the drinking water standard; however, only 177 households requested a water treatment system. Education and technical assistance were integral components of this effort. The lessons learned from this early program included:

- The health effects of nitrate are difficult to convey, because nitrate in water is not visible, and understanding threshold and risk factors associated with drinking water with elevated nitrate concentrations was challenging.
- There is a lack of interest from the public because there were no local reports of nitrate related health problems in the news.
- The GWMA is a large rural area, which makes it challenging to conduct a comprehensive and extensive outreach program without existing community infrastructure.
- Comprehension skills in some households required one-on-one site assistance to verify information and to complete applications.

The Nitrate Treatment Program illustrated the challenge of communicating complex messages to a discrete, hard-to-reach audience. However, it was successful at introducing the nitrate issue to residents within the GWMA.

Water quality samples were also taken from numerous private domestic wells. Figure 20 shows the Nitrate Pilot Project well water test locations.

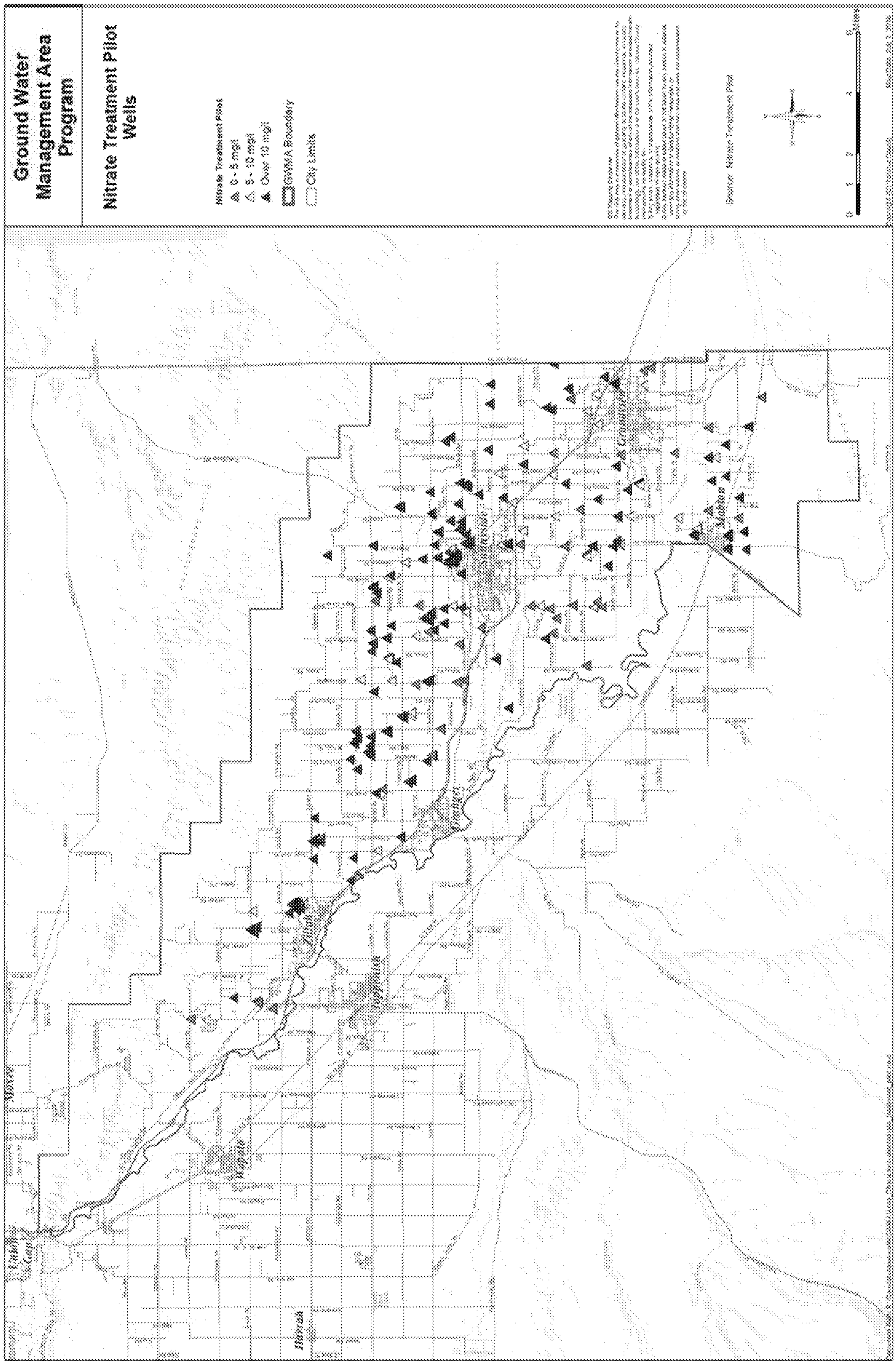

Figure 20 – Nitrate Pilot Project Water Test Locations

GWMA Website

The GWMA website was developed early in the process. The website contains information about the goals and objectives of the committee, meeting notices, agenda, and minutes, upcoming events, products and information. The website was redesigned twice and underwent numerous revisions as GWAC activities, outreach, and the evolving GWMA Program took shape.

The GWMA website (yakimacounty.us/541/Groundwater-Management-Area) serves as the information clearinghouse. It provides a central source of information about the GWAC, the working groups and their products, and links to technical assistance. It is also intended to inform the public about the GWMA Program development.

Although the website link was advertised on nearly every English/Spanish document, presentation and billboard, the visits to the website and the specific pages that were viewed (resource materials) suggested that the primary users were GWAC members and researchers. The education and public outreach work group speculated that the web's most practical use was for agencies and individuals seeking academic information about the GWMA. While efforts were made to make it more inviting to the public (bilingual content, graphics, surveys), there was no evidence that the effort was successful.

Outreach Campaigns:

Two education and public outreach campaigns are described below.

Door-To-Door Public Opinion Survey

A bilingual door-to-door survey was developed to measure what residents in the GWMA served by private wells knew (or didn't know) about their private wells, about nitrates in drinking water, and about the formation of the GWMA. The eight targeted areas encompassed 300 households ranging from Konnowac Pass in the northeast to County Line Road to the southeast. The areas chosen were known to either have high nitrate in groundwater or were located in areas where little data on nitrate levels existed.

Heritage University students collected survey information from 136 households. The results indicated that 69 percent (94 households) surveyed were aware of the potential health risks associated with drinking water with high levels of nitrate. Over half of those surveys had their private well tested for nitrate. Four percent (six households) believed someone in their home had become ill from drinking their well water. None, however, indicated that high levels of nitrate were the source of the illness. One residence reported having an infant, one residence had a pregnant woman, and seven residences reported having a chronically ill individual. Forty two percent of those surveyed had heard of the Lower Yakima Valley Groundwater Management Area. Volume III – Accomplishments contains the survey results.

High-Risk Well Assessment Surveys

This education and public outreach campaign took a closer look at the water quality of private domestic wells in the GWMA, and measured households' understanding of their well maintenance responsibilities, how their own actions might influence groundwater quality, and also measured the awareness of how to protect the quality of their drinking water. Four hundred sixty six sampling surveys were conducted. Water quality samples were also taken. Test locations are shown in Figure 21. Although the sample size was too small to assess data patterns, the lessons learned included:

1) Residents on private wells need to test their wells.
2) Well owners should become more familiar with their wells (e.g., location of their well, find well log, depth of well, condition of well).
3) Understand the possible connection between not testing a well and its likelihood of testing high for nitrate.

All of the extensive education and public outreach material are consolidated in Volume III – Accomplishments.

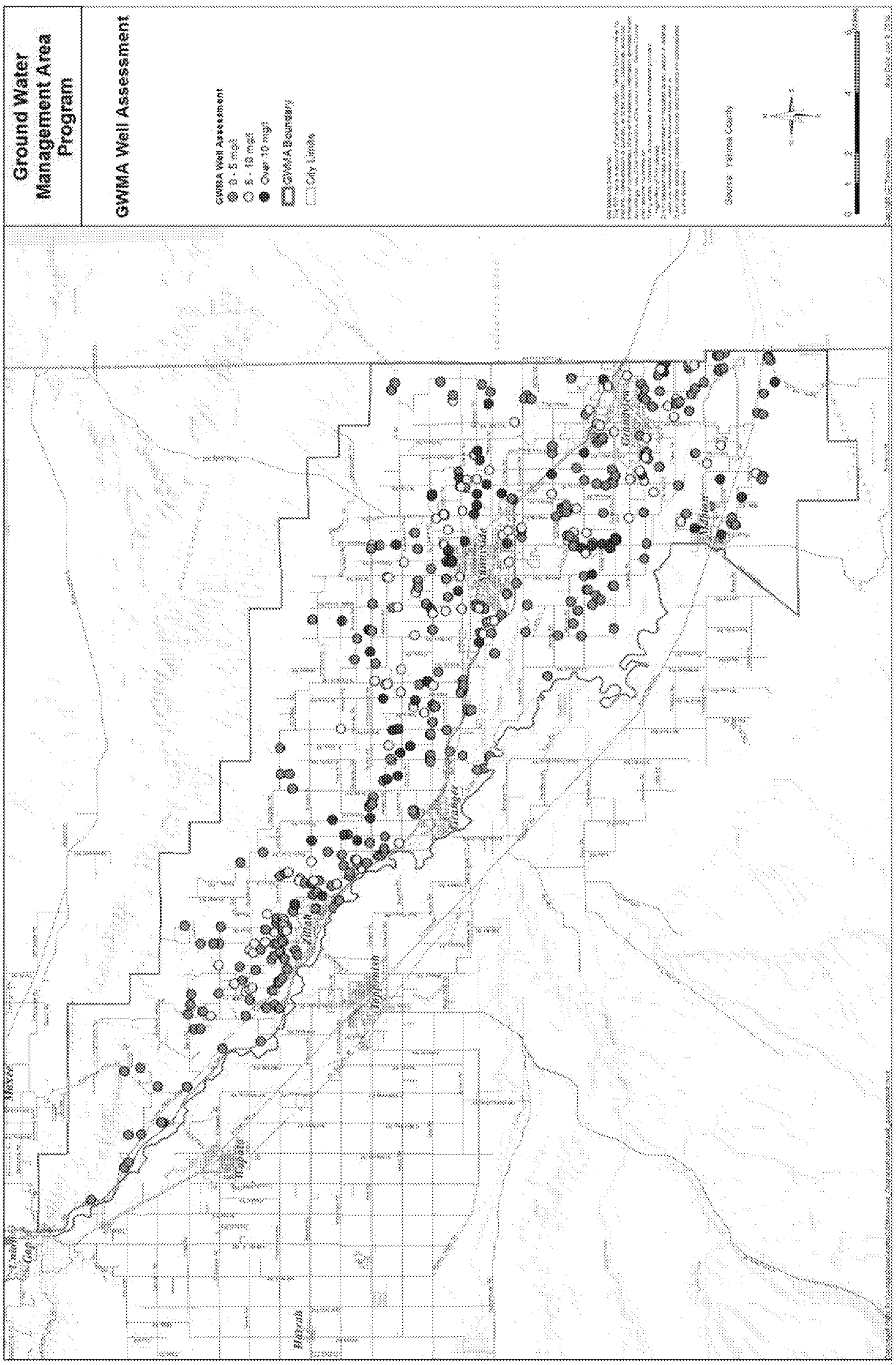

Figure 21 – High Risk Well Assessment Test Locations

Best Management Practices Identification

The GWMA initially contracted with a consulting firm, HDR to produce a list of potential Best Management Practices (BMPs) that may be applicable to agricultural, industrial, urban, and domestic activity within the GWMA. The Irrigated Agriculture Workgroup of the Groundwater Advisory Committee reviewed the HDR produced list and selected those BMPs they felt particularly relevant to their respective operations. Those BMPs are set forth in Appendix G. The Livestock/CAFO Workgroup of the Committee elected to review the BMPs listed by the Natural Resources Conservation Service (NRCS) to determine those particularly relevant to livestock/CAFO operations. Those BMPs are set forth in Appendix H.

Groundwater Monitoring

Groundwater monitoring efforts include a number of planning and data assessment documents, a quality assurance project plan, a drinking water sampling effort, and the siting and installation of an ambient groundwater monitoring network. These items are discussed in greater detail below. Additionally, the published documents are contained in Volume III-Accomplishments.

Groundwater Monitoring Plan

The GWMA began the planning process by consolidating groundwater quality data and considering different types of groundwater monitoring programs. Pacific Groundwater Group (2013g) conducted an analysis of existing groundwater quality data by creating a database containing over 2,500 groundwater nitrate results from local, state and federal government agencies, and well locations of almost 7,800 wells. Analysis of this data indicate that well depths range from 1 foot to over 2,700 feet below land surface. Approximately half of these wells are shallower than 136 feet. Nitrate concentrations are at or below the natural background concentration of 0.3 mg/L for 14.3% of samples. Nitrate concentrations exceed the drinking water standard of 10 mg/L for 12.9% of samples. Trend analysis was also conducted for this dataset despite the limitations. Both the median and mean concentrations have increased since 1975 (PGG 2013g).

Figure 23 consolidates groundwater quality results from all monitoring efforts.

This information was used to propose potential groundwater monitoring projects. Pacific Groundwater Group (2013g) identified the following types of monitoring:

- Spatial data gaps
- Hotspots
- Increasing trends
- Ambient groundwater monitoring – installed 30 monitoring wells in randomly placed locations to assess the long-term groundwater quality of the GWMA over time. A

comprehensive groundwater monitoring network could include monitoring wells and existing private domestic wells.

- Drinking water assessment – determining the quality of water from common water supply aquifers used by individuals drinking water from private domestic wells.
- BMP effectiveness monitoring
- Health risks

The highlighted groundwater monitoring programs were initiated by the GWAC and are described in greater detail below.

The GWAC developed an Interim Final Groundwater Monitoring Plan (PGG 2014e) in order to establish a network of wells and field procedures to evaluate current and future nitrate concentrations in groundwater.

Quality Assurance Project Plan

A quality assurance project plan (QAPP) was developed for groundwater monitoring efforts. This QAPP specifies how samples will be collected, the data quality objectives, the station quality objectives for various sampling efforts, the analytical data quality objectives, the quality control checks and the data validation and usability requirements. All samples must be analyzed by an accredited laboratory. (PGG 2013d)

Data Analysis

Statistical methods for analyzing groundwater quality data are described in (PGG 2013g).

Pacific Groundwater Group (2013g) recommends basic summary statistics for all data sets considering: the number of samples, the number of locations, the number and percentage of non-detects, minimum, maximum, mean, median, variance and standard deviation. The following statistical procedures are recommended:

- Data distribution determination
- Comparison to natural background
- Comparison to groundwater quality criterion
- Variability with depth
- Mann-Kendall Trend Test
- The purpose built wells for the ambient groundwater monitoring network provide the basis for future trend analysis. Mann-Kendall Trend Test is recommended, which requires a minimum of 10 data points per well, adjustments for outliers and seasonality.
- Trend analysis should not be conducted with existing data in the database if QA/QC data are not available (PGG 2013g).

The statistical methods for analyzing groundwater data are supported by other publications (Ecology 1996; Visser et al. 2009; Hirsch et al. 1991).

Drinking Water Quality Assessment

The U.S. Geological Survey (USGS) conducted an intensive groundwater nitrate sampling effort from drinking water sources. In 2017, nitrate samples were collected from 156 private domestic wells on six occasions, with 1,059 samples collected. Additionally 24 surface water drains were also sampled for nitrate concentrations (figure 22).

Nitrate concentrations in groundwater ranged from less than 0.04 to 45.2 mg/L. The average nitrate concentration was 6.1 mg/L. More than 20 percent of samples from the domestic wells had nitrate concentrations that exceeded the drinking water standard of 10mg/L. Twenty six percent of wells sampled had at least one nitrate concentration above the standard, and nitrate was not detected in 15% of well sampled. (USGS 2018)

Nitrate concentrations in surface drains ranged from 0.04 mg/L to 25.2 mg/L. The average nitrate concentration was 5.5 mg/L. Almost 13 percent of drain samples had nitrate concentrations that exceeded the drinking water standard of 10mg/L. Thirty-three percent of drains sampled had at least one nitrate concentration above the standard, and nitrate was not detected in 5 percent of drain sample sites. (USGS 2018)

This report and the supporting QAPP (USGS 2017) are contained in Volume III – Accomplishments.

Ambient Groundwater Monitoring Network

The GWAC decided that establishing an ambient groundwater monitoring network was a priority to establish a baseline of groundwater quality conditions and to track concentration changes over time. The foundation of this network is a network of 30 purpose-built wells (monitoring wells) completed at the water table. The water table is targeted since little data from this zone exists and because concentration changes associated with land use management changes will occur here first. Additionally the goal was to install a sufficient number of wells to adequately represent groundwater conditions across the GWMA and to locate the wells used a random location method. Pacific Groundwater Group (2016) identified the preliminary well drill sites and ranked them statistically. A contract was signed, and wells were installed in Yakima County public right-of-ways as close to the location site as possible in 2018.

Monitoring of these wells is expected to continue during the implementation phase and is contingent on funding.

Groundwater Hotspots

Hotspots are areas where the maximum nitrate concentrations exceeds 20 mg N/L. Seventy-one hotspots were initially identified in 2013 using the water quality database of over 2,500 existing groundwater nitrate results (PGG 2013g). Further refinement of these areas was one of the potential monitoring programs that was considered by the GWAC, but was not chosen due to limited resources.

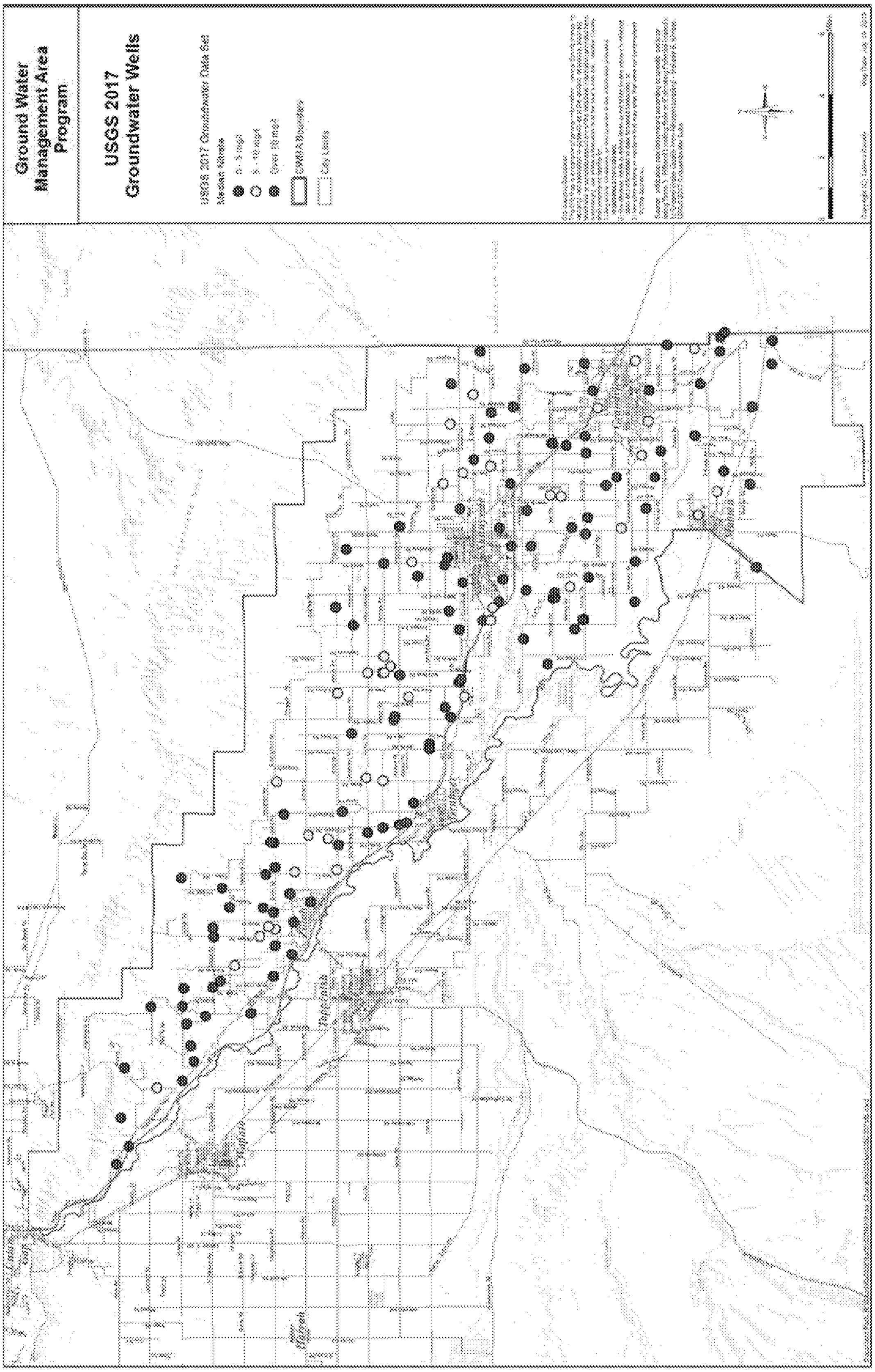

Figure 22 – SGS 2017 Groundwater Well Test Locations

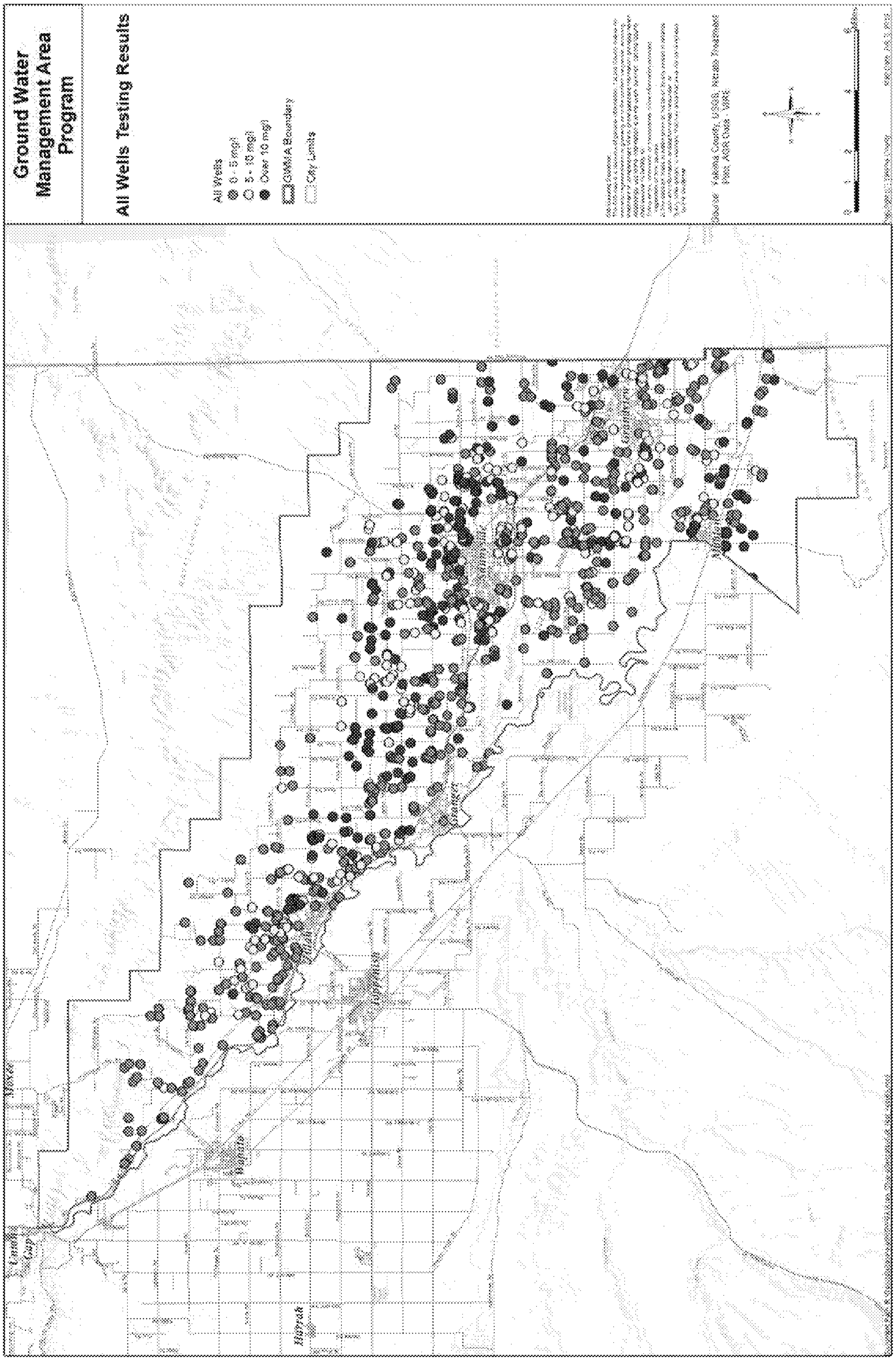

Figure 23 – All Water Quality Sampling Locations (3 Testing Programs)

Deep Soil Sampling Program

Deep soil samples were collected anonymously from agricultural fields in the spring and fall. A total of 175 fields were sampled at one foot increments down to six feet below land surface. Additionally each farmer was asked to fill out a survey about crop, water and nitrogen practices. The South Yakima Conservation District and Landau Associates performed four rounds (Fall 2014, Spring 2015, Fall 2015, and Spring 2016) of deep soil sampling (DSS) on agricultural land in the GWMA. All participants volunteered to participate in the Program, subject to the condition that the physical location of sampling was anonymous and undisclosed. A quality assurance project plan (QAPP) was developed, and was followed during sampling (PGG, 2014c).

The purposes of the deep soil sampling included:

1) Provide baseline data regarding the nitrogen content (nitrate, ammonium, and organic matter) of soils underlying a variety of soil, crop, and irrigation systems that represent a cross-section of agricultural activities.

2) Provide an initial assessment of current nitrogen and water management practices in place today and in the past.

3) Provide information regarding availability of soil nitrogen to crops.

4) Provide the foundation for a technically based education program.

5) Provide information about project design, practical realities, time requirements, and costs that can be used in developing subsequent project scopes.

Because of the anonymity of the data and the inability to track soil nitrate concentrations from one field over time, there are limitations with how this data can be used. Appendix F includes the deep soil sampling data, a discussion of the limitations, and two different preliminary analysis efforts. These analyses were conducted as an attempt to gain insights from the sampling effort. This initial effort also provides insights for overcoming information gaps that would enhance future deep soil sampling.

Identification of Nitrogen Sources

A nitrogen availability assessment was completed to identify sources of nitrogen and determine their relative contribution. This assessment establishes a scientific baseline of the potential amount of nitrogen available for transport from different nitrogen sources within the GWMA. Nitrogen available for transport is nitrogen that has the potential to move from the land surface or soil profile into groundwater. The study did not calculate how much actually is transported to groundwater. (WSDA 2018)

This assessment is a refined estimate of nitrogen availability using local information where available. This is a qualitative assessment rather and a quantitative assessment, and since the data is incorporated into Yakima County's GIS database, it is a living document that can be refined in the future.

Relative nitrogen contributions are estimated for the major sources in the GWMA, and are compiled in Table 2 and Figure 4.

Geographic Information System

A geographic information system (GIS) database was developed specifically for the GWMA. Yakima County maintains this database which includes information on land use, water quality and other natural resource data. All data generated by the GWAC was included in the GIS database. This includes nitrogen available from sources (WSDA, 2018), and drinking water quality results collected from private domestic wells (USGS, 2018).

Data from these two efforts were mapped and are presented in the following figures:

- Figure 24. Total Available Nitrogen
- Figure 25. Available Nitrogen with Drinking Water Nitrate Concentrations
- Figure 26. Soil types with Drinking Water Nitrate Concentrations
- Figure 27. Canals and Drains with Drinking Water Nitrate Concentrations.
- Figure 28. Crops with Drinking Water Nitrate Concentrations
- Figure 29. Point sources with Drinking Water Nitrate Concentrations
- Figure 30. Residential On-site Sewage Systems with Drinking Water Nitrate Concentrations

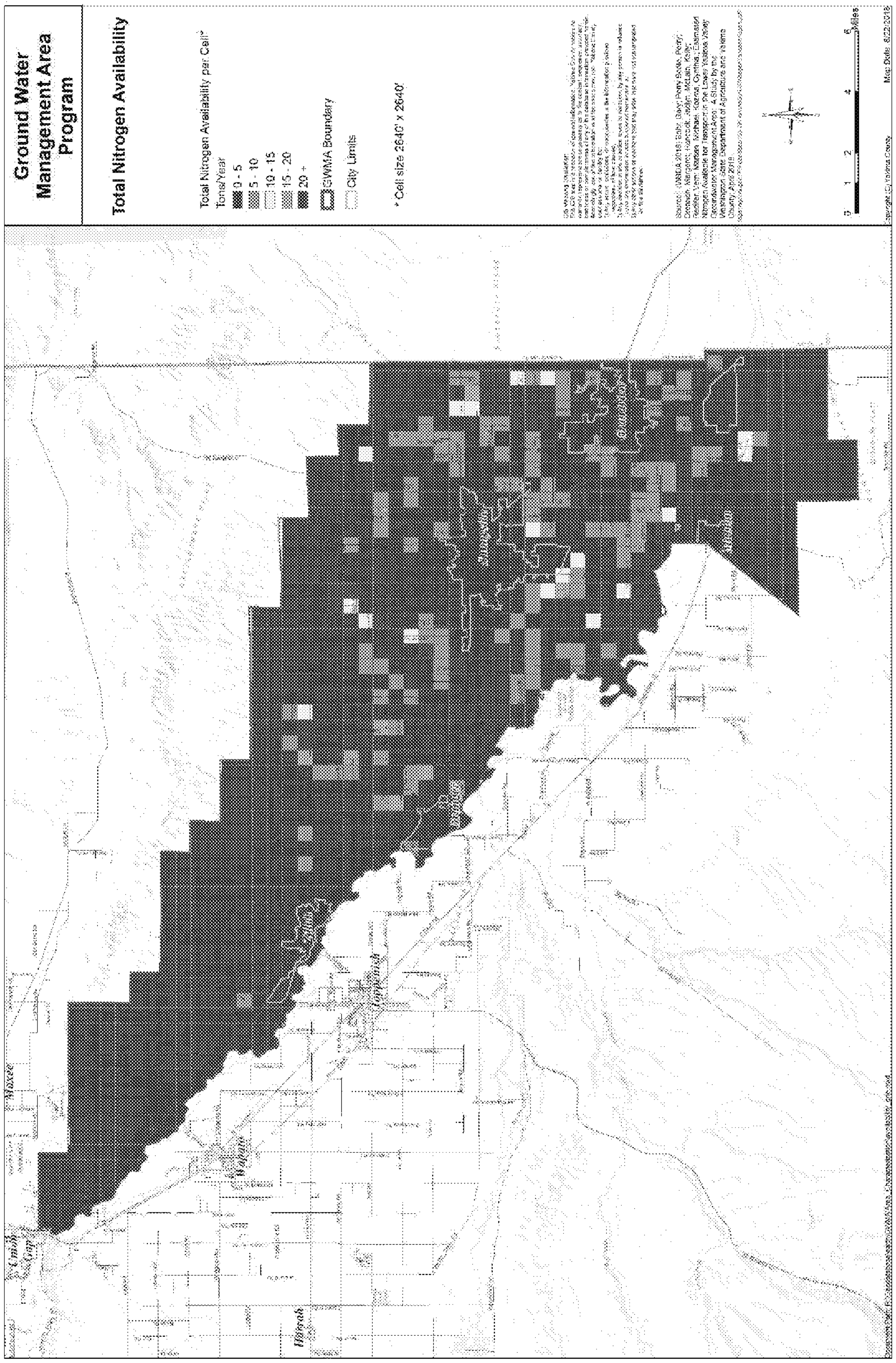

Figure 24 – Total Nitrogen Availability

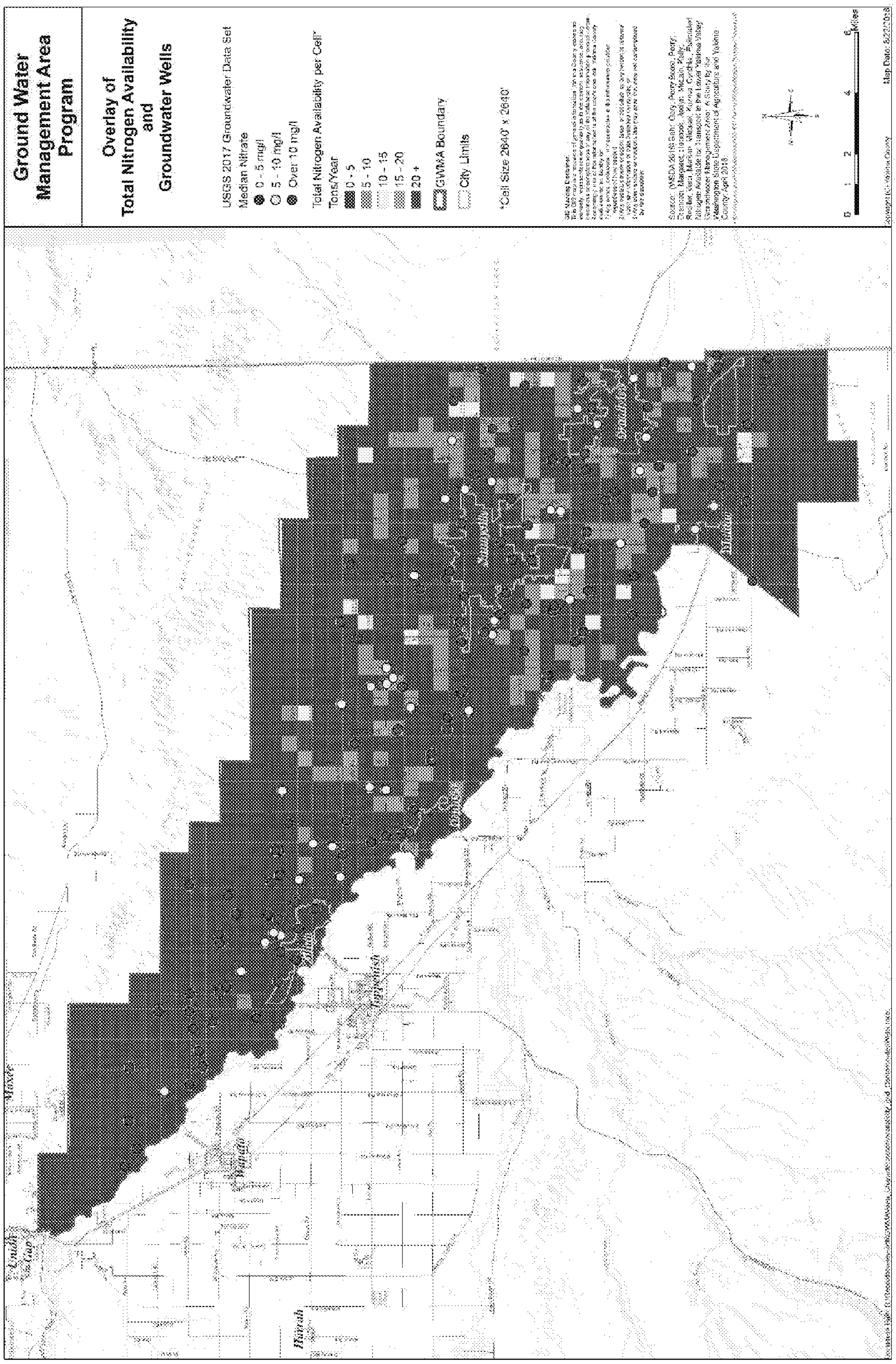

Figure 25 – Nitrogen Availability and USGS Wells

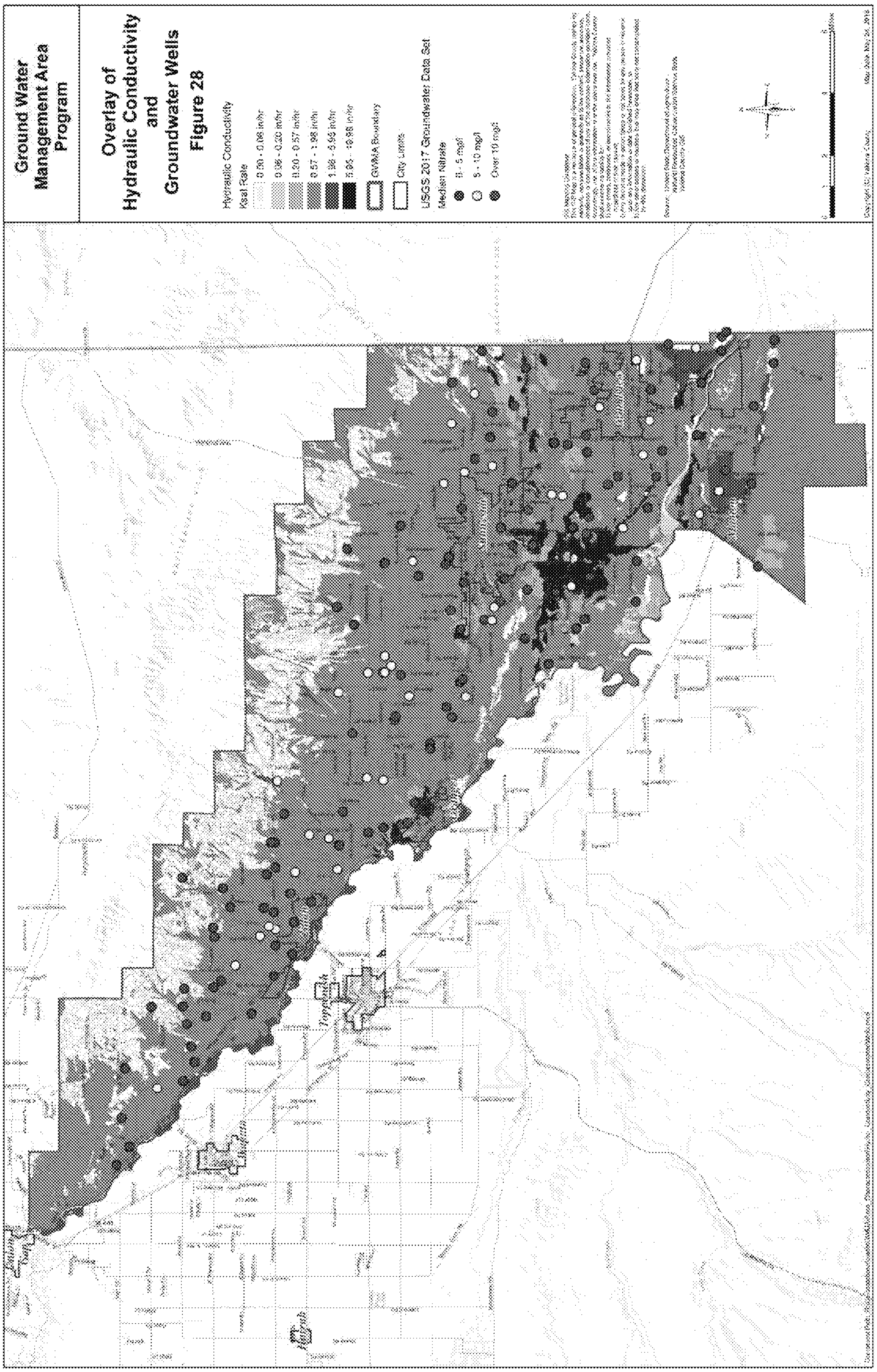

Figure 26 – USGS Well Data Overlaid on Soil Types Simplified by Hydraulic Conductivity Groups

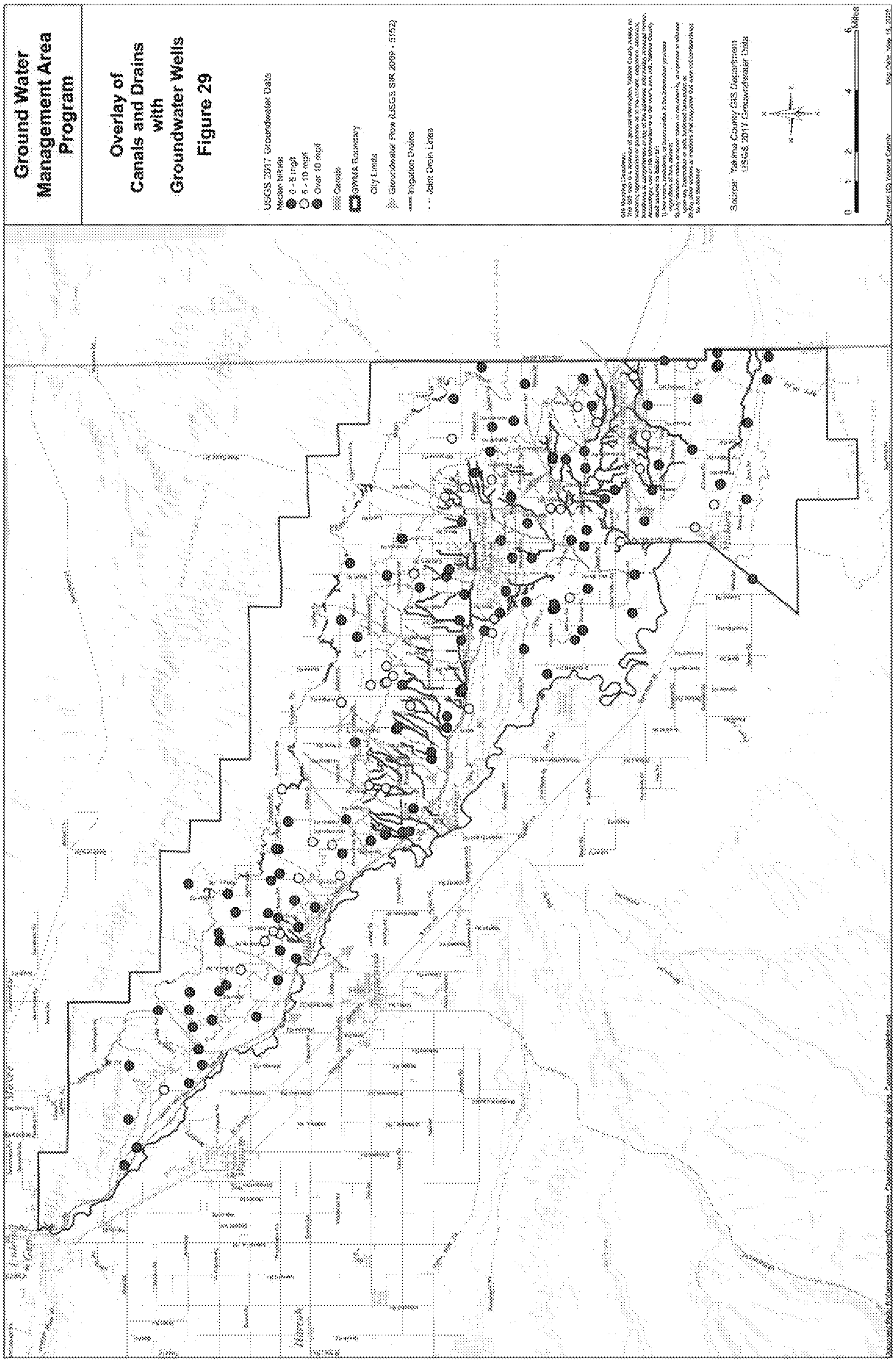

Figure 27 – USGS Well Data Overlaid on Irrigation Canal and Drain Information

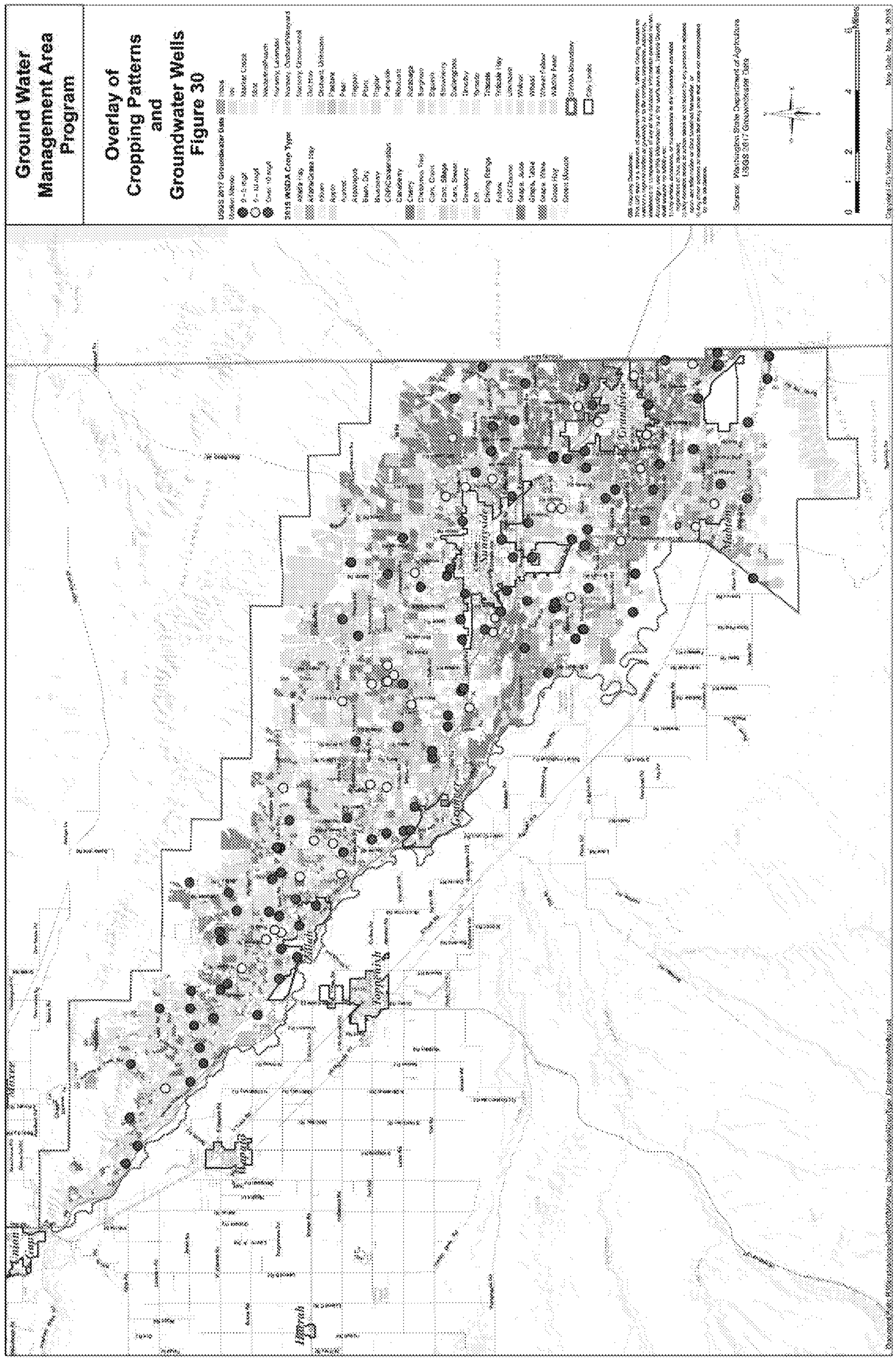

Figure 28 – USGS Well Data Overlaid on Cropping Patterns

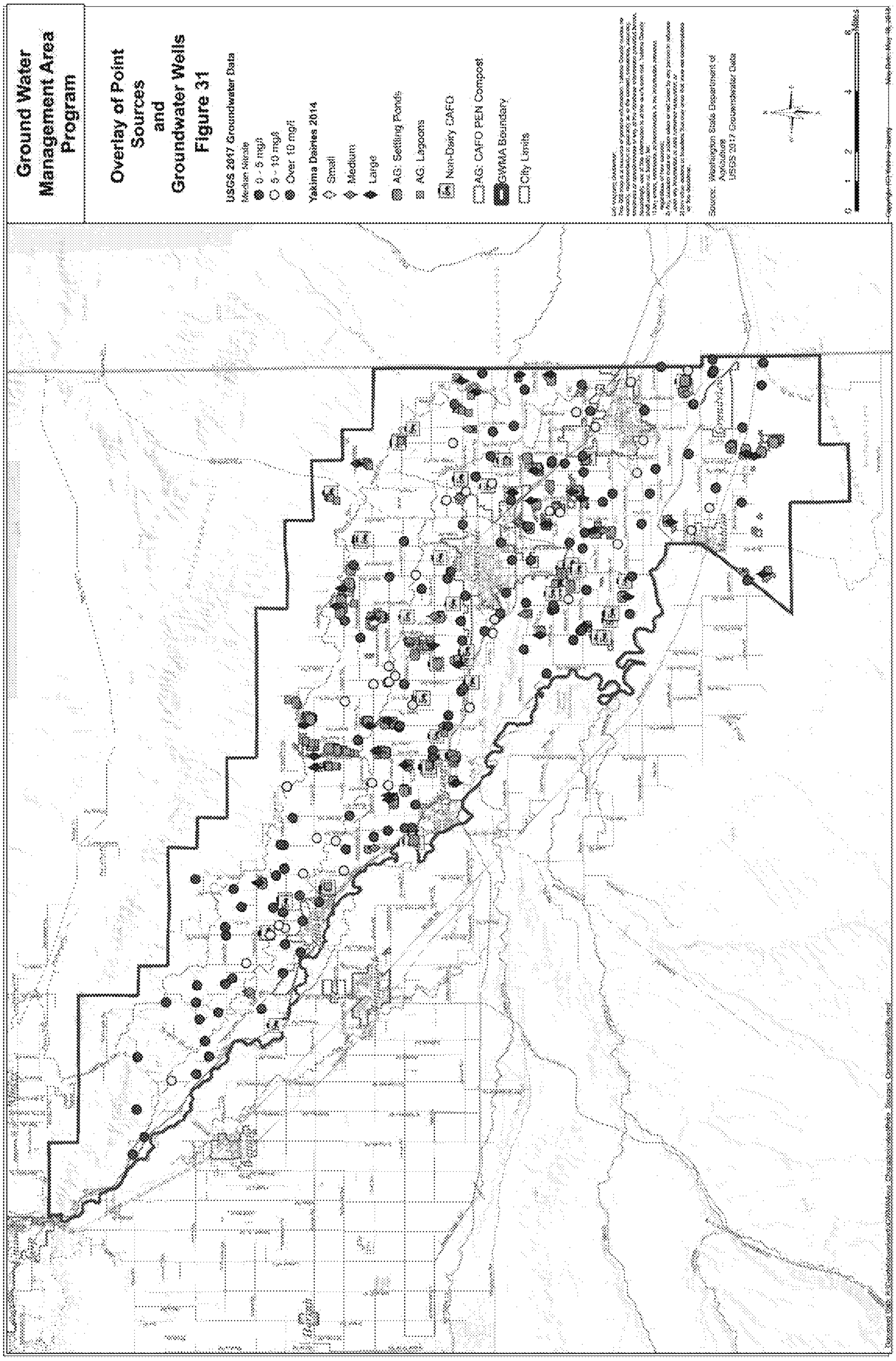

Figure 29 – USGS Well Data Overlaid on Map of Point Sources

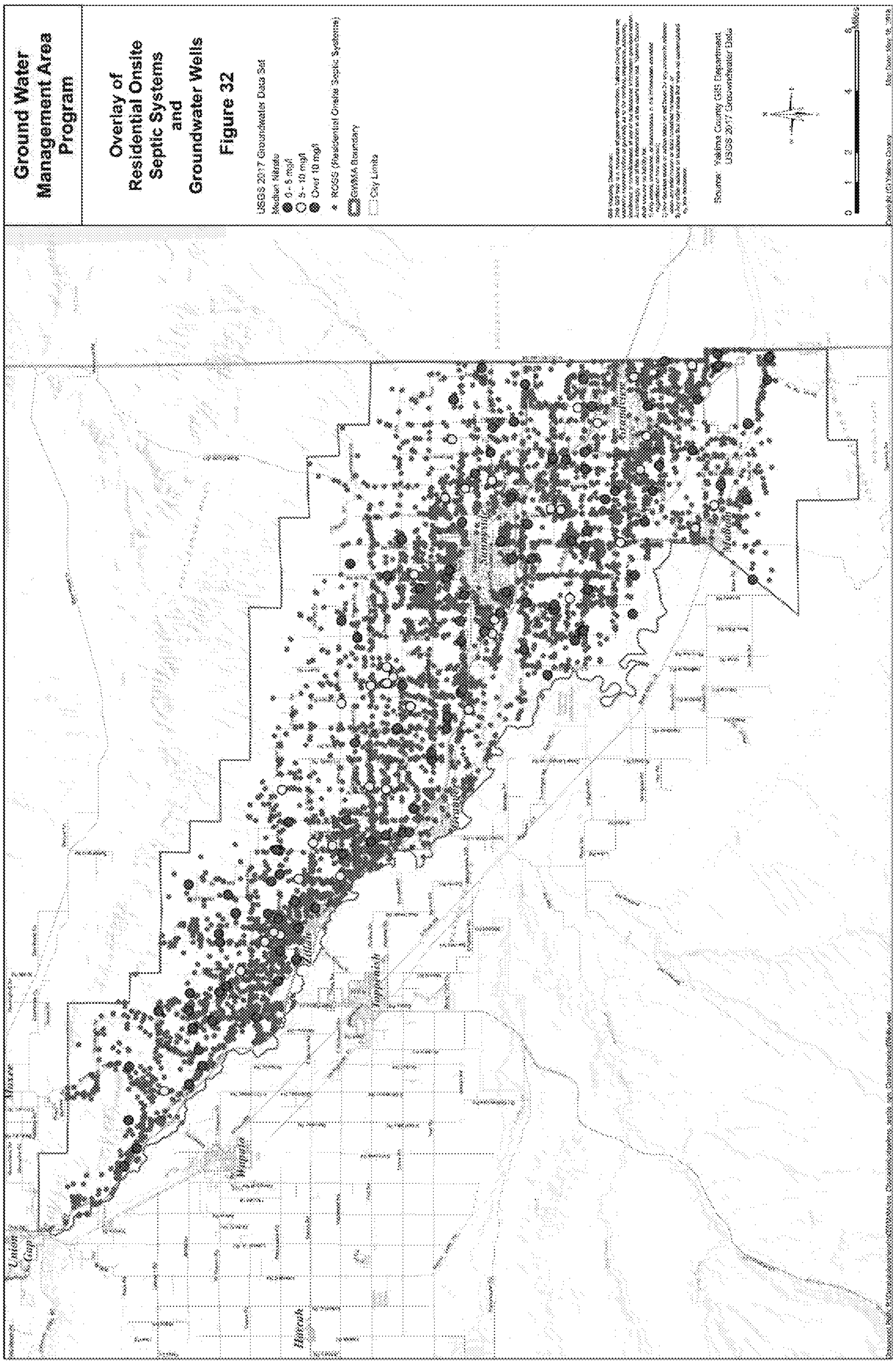

Figure 30 – USGS Well Data Overlaid on Map of On-site Sewage Systems

Recommended Actions

The GWAC developed a list of recommended actions (Appendix J). These actions were prioritized from the list of alternatives presented in Appendix I, by a voting process from GWAC members. GWAC members placed a value or -3 to +3 with each recommendation, and the results were totaled. The following recommended actions are listed in order of priority. The number of GWAC votes and the implementing agency are listed in the parentheses.

Recommended Actions

1. **Install Ambient Groundwater Monitoring Wells. (42 – Yakima County)** Monitoring well construction.
2. **Collect data from Ambient Groundwater Monitoring Wells. (42 – Yakima Health District)**

   Study short-term seasonal variations in nitrate concentrations over next year or two and address effects of changes in nutrient application over the agricultural cycle. Study long-term trends that develop over several years to track whether time-based performance objectives are being met.
3. **Establish a Lead Agency responsible for implementation and oversight of the GWMA Groundwater Management Plan and acquisition of stable funding to support their activities. (41 – Yakima County)**

   Administer the Groundwater Quality Program (subject to state funding). Administer funds and distribute to other entities by subcontract. Host the GWMA website. Maintain a GIS database on the GWMA.
4. **Publish and distribute homeowner guide on how to maintain septic systems. (40 – Yakima Health District)**
5. **Fund SYCD, through State Conservation Commission budget, for projected educational, administrative, nutrient management planning, engineering, cost share, and lending activities. (39 – WCC)**
6. **Establish a local forum for disseminating information and facilitating technical exchange regarding Best Management Practices (BMPs) for irrigated agriculture and livestock management and groundwater protection. (36 – SYCD and WCC)**
   Prepare a fact sheet/develop outreach campaign to growers that explains agronomic rates, applying nutrients at the right time/right

place/right amount. Endorse and distribute materials that will educate producers about the facts related to all fertilizer types, including livestock nutrient and the science of groundwater protection.

7. **Develop a post-GWAC agricultural producer education and outreach campaign. (36 – WCC, WSU Extension Service, WSDA, Ecology, Yakima County, SYCD, and agriculture associations)**

   Create a broad-based advocacy group (e.g., regulatory agencies, agricultural industry associations such as the Farm Bureau, Dairy Federation, hop growers, wine grape growers and producers) to carry out the educational components. Create a central repository (e.g., website) of agricultural information that provides technical assistance to growers and producers, provides education on nitrate, and identifies BMPs specific to each local agricultural industry. Address consequences of too much irrigation. Recommend technological improvements in irrigation that permit easier management of water. Provide descriptions of specific improved technology. Explore economic viability of technological advancements, BMP implementation, irrigation water management, soil nutrient management, and manure management and application.

   Elements could include:

   - Encouraging commodity groups to provide education on water management and fertilizer use through regular meetings.
   - Distributing information to producers on what can happen with applied nitrogen, what should be applied, and reasonable agronomic rates of application.
   - Encouraging agencies and subject matter experts to make presentations at trade shows.
   - Asking agricultural consultants to share the latest BMP developments with their clients.
   - Increasing livestock operators' awareness of the need for procedures for proper management of animal manure.
   - Providing producers with information on funding sources (e.g., industry, government, educational institutions, industry associations, etc.) that will improve their ability to apply BMPs.
   - Enlisting partners (farm bureau/federations/associations) to host workshops/informational meetings regarding GWMA goals and recommendations.

8. **Establish or maintain ongoing, extended funding necessary for the Yakima County Department of Public Services and the Yakima Health District to actively participate in water quality improvement, testing,**

monitoring, scientific data analysis, and infrastructure development. (35 – Ecology, Yakima County and Yakima Health District)

Collect data to track water quality improvement progress and nutrients generated, applied, or exported within the GWMA. Generate data through soil testing, Ambient Groundwater Monitoring Plan implementation including purpose built and existing wells, sampling of liquid and solid waste to be field applied, composted, or exported, the CAFO General Permit, and tracking nutrients applied by non-dairy operations. Collect, analyze, and interpret data to track water quality improvement progress, nutrients imported, generated, applied, or exported, which will inform the implementation of an Adaptive Management Plan within the GWMA.

9. **Monitor nitrate concentrations of irrigation water at headgates. (35 – Roza-SVID Joint Board of Control)**

   Report nitrate concentrations annually to Department of Ecology.

10. **Design and implement pilot studies focusing on innovative farm techniques which reduce nitrogen loading to crops and monitor results. (34 – WSDA)**
11. **Provide financial assistance for implementation of Irrigation Management Plans. (32 – NRCS and Ecology)**

    Details include 1) conversions from rill irrigation to sprinkler or drip irrigation, 2) installation of flow meters and moisture meters to reflect over-irrigation, high water table, drought conditions, 3) the cost of hiring third-party sampling, measuring equipment, personnel or self-test kits, 4) management of sprinkler systems so they do not drive nutrients past the root system.

12. **Study potential nitrate contamination attributable to improperly operated septic systems. (32 – Yakima Health District)**

    Consider restoration/retrofit of older septic systems through incentives or county property tax breaks. Require nitrogen-reducing technologies for on-site septic systems where appropriate. Assist hobby farmers to locate ROSS drain fields on their property to avoid animal farming over the drain field.

13. **Encourage advanced irrigation management. Integrate management of synthetic/organic fertilizers and application of water. (31 – SYCD, WSDA and WSU Extension Service)**

    Recognizing that there is significant cost involved in changing an irrigation system, look for strategic opportunities where the use of more advanced irrigation management systems could have the greatest benefit for reducing nitrogen impacts to groundwater. One example of advanced irrigation management is electronic sensor irrigation water management (IWM). Identify federal, state, and local incentive programs (like EQIP -- NRCS Environmental Quality Incentives Program), such as grants, and low-interest loans, to facilitate a transition to more advanced irrigation management in those areas. Provide financial assistance for 1) conversions from rill irrigation to sprinkler or drip irrigation, 2) installation of flow meters and moisture meters to reflect over-irrigation, high water table, and drought conditions, 3) the cost of hiring third-party sampling, measuring equipment, personnel, or self-test kits, 4) management of sprinkler systems so they do not drive nutrients past the root system. Establish a voluntary irrigation management cost-share program from which data may be shared with the public.

14. **Educate producers regarding application of nutrients at agronomic rate. (30 – South Yakima Conservation District, Washington Department of Agriculture, Washington State University, Private Industry and Producers)**

    Develop technologies and provide information about improvements made in nutrient management and agronomic rate application of fertilizer by specific developing technologies.

15. **Develop a bilingual, health-risk education and outreach campaign. (28 – DOH, Yakima Health District and Yakima County)**

    Establish a public education program regarding nitrate pollution and health risk over a 5- to 10-year period. Partner with UW Pediatric Environmental Health Specialty Unit to continue training local healthcare providers to recognize and address nitrate risk in their patients (pregnant women and infants up to six months).

16. **Contract with USGS to collect data from water well system per 2017. (28 – Yakima County)**
17. **Encourage municipalities within the GWMA to extend municipal sewer systems within urban growth areas and retire ROSS and LOSS; alternatively, extend public water systems. Encourage connection of residences within urban growth zones to sewer systems extended by municipalities. (26 – Yakima County)**
18. **Identify and support opportunities, including education research institutions for private, public, and industry investment in technology and management of fertilizers and manures, including separation of solid and liquid wastes. (26 – WCC)**
19. **Operate a mobile irrigation lab to assess the efficiency of current or advised irrigation practices, either through a singular lab or component parts. (25 – WSU)**

Inform farmers of the relative propensity of wheel lines, center pivots, and drip lines to cause leaching and that fertilization and supplemental irrigation beyond the optimum rate will not necessarily produce better yields or higher profits without serious side effects. Advise regarding corn and triticale water practices.

20. **Continue research of water management with application of agricultural nutrients. (25 – WSU)**

    Develop water sorption graph or chart. List volumes of water applied, soil types, infiltration rates, water holding capacity, absorption/compaction rates, depths to water, pre-season and post-season appropriate moisture levels, evapotranspiration rates.

21. **Inform farmers of those BMPs prioritized by Livestock/CAFO and Irrigated Agriculture Work Groups to reflect greatest effectiveness in nitrate reduction. (25 – WSDA and SYCD)**

    Focus implementation of BMPs based on information and data included in the Nitrogen Availability Assessment, Soil Sampling Program, Ambient Groundwater Monitoring Plan, USGS Reports, and other similar scientifically based publications. GWMA: Publish lists as appendices to GWMA Program. WSDA: List Lower Yakima Valley GWMA-specific BMPs; determine who implements each BMP and who monitors it. Determine the time frame in which to measure/monitor each BMP. SYCD: provide farmer-specific consultation.

22. **Continue to provide underlying soils information to individual livestock operations, provide same for all irrigated agriculture. (25 – WSDA and SYCD)**

    So that individual property owners can evaluate contamination potential, already in DNMP process.

23. **Monitor changes occurring in agricultural operations. Evaluate whether those changes positively affect improvement in groundwater quality. (25 – SYCD and WSDA)**

    Requires cooperation of producers & landowners, multi-year effort to account for crop rotation, dry vs. wet years, changing technology, decades to monitor groundwater quality change. WSDA: prepare report to Legislature and Department of Ecology.

24. **Establish a multi-year Deep Soil Sampling Program where farmers subscribe for a duration with pre-determined fiscal remuneration for completed sampling. Cost share with farmer. Farmer to provide checklist indicating performance with BMPs. Test throughout growing year, in**

order to observe effects of fertilization throughout year. Share data with public. (25 – SYCD)

Farmers would subscribe for a duration with pre-determined fiscal remuneration for completed sampling. Cost share with farmer. Farmer would provide checklist indicating performance with BMPs. Testing would occur throughout growing year, in order to observe effects of fertilization throughout year. Data grossly accumulated would be shared with public without attribution to individual farmers. Anecdotal results of deep soil sampling carried out by SYCD with farmers with pre-existing relationship with SYCD were informative. Word-of-mouth reporting within farmer community greatly increased acres sampled.

25. **Streamline current regulatory enforcement activities. (25 – EPA, WSDA, and Ecology)**

    Improve customer service and protocols, increase clarity of process, escalate enforcement for facilities not following management practices, identify methods to discourage repeatedly unfounded complaints, and improve overall transparency.

26. **Analyze the trends of nitrate data contained within reports required by NPDES and SWD permits. (23 – Ecology)**
27. **Integrate use of animal waste and synthetic fertilizer. (23 – WSU and livestock producers)**

    Research chemical integration of animal manure and synthetic fertilizers with objective of balancing nutrient application amounts in order to maximize crop production and full nitrogen uptake.

28. **Create Irrigation Management Plans (similar to Nutrient Management Plans) for farms over a minimum size and provide financial assistance for implemented plans. (23 – SYCD, WSDA, and WSU Extension Service)**

    Use available techniques to determine how much and when irrigation is needed instead of irrigating according to a prearranged schedule. Analyze irrigation practices to discover whether frequency or volume creates greater propensity for leaching. Manage sprinkler systems so they do not drive nutrients past the root system. Improve micro-irrigation system design and operation. Schedule water and nitrogen application according to the need for optimal crop yields. Monitor the timing of application of fertilizers to fields and how much water was then applied.

29. **Complete NRCS Technical Note 23 inspections on all waste storage ponds (lagoons) within the GWMA boundaries. (23 – WSDA)**

30. **Develop a plan for finding and decommissioning abandoned wells in the next 12 months, using the GWMA as a pilot project. (23 – Ecology)**

    Educate the public regarding liability of an ill-secured well, and the importance of the integrity of wells, particularly those without a well log. Educate realtors and banking industry officials about disclosure of abandoned wells in property transfers. Compare Google Earth to GIS images to determine where building or usage changes indicate possible well usage changes. Focus first on hotspot high density areas in GWMA. Ground truth suspected problem wells. Offer incentives for property owners to identify and properly abandon wells. Offer grant funding to Yakima Health District or professional engineers for well inspections and to assist in abandoned well decommissioning. Provide some form of protection for self-reporting of abandoned or improperly decommissioned wells.

31. **Explore investment in animal and agricultural waste to energy technology. (22 – US DOE and USDA)**

    Explore state of technology, economic viability, return on investment (national corporate research & development/ governmental incentives).

32. **Adopt and Implement an Adaptive Management Plan. (22 – Yakima County)**

    Utilizing data collected, progress made, or lack of progress, to inform the community on adjustments that need to be implemented. Plan would incorporate necessary adjustments to availability of technology, education and outreach, tracking exports, land use regulations, treatment systems, and other changes to inform decision makers regarding management changes necessary for a successful Program.

33. **Identify and support opportunities, including educational research institutions, for private, public, and industry investment in technology specific to addressing nitrate contamination in groundwater. (20 – EPA and Ecology)**
34. **Determine, prior to issuing or reissuing LOSS permits, that all employee counts are regularly reported. (19 – DOH)**

    So that the LOSS will continue to operate as designed.

35. **Quantify the nutrient value and rate of release of nitrate from livestock waste under various Lower Yakima Valley conditions to become part of nutrient management guidelines. (19 – WSDA and WSU)**

36. **Require new developments outside towns to address potential impacts on groundwater quality. (19 – Yakima Health District)**

    Work with Yakima County Planning and Building Divisions' permit program to identify methods of permitting while reducing impacts to groundwater.

37. **Develop and implement Nutrient Management Plans for all farmers. (19 SYCD and Livestock producers)**

    Mandatory or Voluntary. Farming operations currently are not required to hold permits or prepare a Nutrient Management Plan.

38. **Develop strategies for marketing the economic, fertilizer value, and soil enhancing properties of appropriate application of manure and other livestock wastes. (18 – WSDA)**
39. **Encourage appropriate use of surface banding ("dribbling," "stripping" of liquid fertilizer, "broadcasting" or prompt incorporation of manures and fertilizers after application to cropland. (18 – WSDA and SYCD)**

    Broadcast is effective for corn, alfalfa, triticale. Incorporation should occur within 24 hours.

40. **Make grants and allocate cost share funding or other funding assistance to people implementing environmental protection measures affecting groundwater quality. (17 – Ecology and WSDA)**

    Assign personnel to investigate which environmental protection measures utilized by irrigated agriculturalists and livestock/dairy producers have positive influence on groundwater quality and explore means to share costs of implementing such measures. (Coordinated DOE, WSDA, Conservation District program). See NRCS Environmental Stewardship Program (2012). Also WCC, Voluntary Stewardship Program (Bill Isler), USDA Rural Community Assistance Group environmental program.

41. **Identify and support opportunities, including education research institutions for private, public and industry investment in technology and management of fertilizers and manures, including separation of solid and liquid wastes. (17 – WSDA)**

    WSDA construct GWMA administrative program.

42. **Establish time-based performance objectives against which well-monitoring data can be compared. (16 – Ecology and DOH)**

    E.g., number of at risk wells, BMP implementation, funding success, reduction in number of underperforming farming practices. Use both method-based measurement and performance-based measurement.

43. **Require new developments to address potential impacts on groundwater quality. Limit new development utilizing septic system where soil filtration rate is high, where housing density is already big, where nitrate concentration is already great downstream of the septic plume. Consider the nitrate density element (# of systems per-area) when approving proposed septic systems in order to reduce the nutrient nitrogen in domestic wastewater discharged from OSS. (15 – Yakima County)**

    Recommendations for conditions on issuance of building permits. Determine "density" evaluation criteria. Including those technologies verified by the U.S. EPA's Environmental Technology Verification Program: fixed film trickling filter biological treatment, media filter biological treatment, and submerged attached-growth biological treatment. Recommend use of anaerobic digestion in waste storage lagoons as a BMP.

44. **Perform an engineering study of water supply alternatives. (14 – Yakima County)**

    Possible alternatives: 1) Discontinue use of contaminated shallow wells. Build new 1,500-foot community wells. 2) Rebuild, repair, or replace poorly constructed wells. 3) Construct a potable water line from nearby developed area into deadhead water stations at central rural location (permit potable water collection at deadhead water stations). 4) Offer incentives to drill deeper wells or connect households on private wells near community water systems to connect to a community water system (Nitrate Treatment Pilot Program – June 2011).

45. **Review applications for and issue exemptions for agricultural composting operations in a manner that protects public health and the environment, as required by state rules and regulations. (12 – Ecology)**

46. **Provide funding for municipalities to replace aging sewer system infrastructure and ensure proper system maintenance to reduce nitrate leaching. (11 – Municipalities)**

    Municipalities need to estimate costs and system integration.

47. **Develop an urban and hobby agriculturalist education and outreach campaign. (10 – Yakima County)**

    Provide information targeted to small farm/hobby farm/ranchettes about manure management. Publish and distribute homeowner guides on proper septic system construction, operation, and maintenance. Educate the public, particularly in towns, about lawn and garden nitrogen applications' contribution to nitrate concentrations. Recommend against farming around a water well.

48. **Contract with USGS to do particle tracking model study to indicate where groundwater moves faster (permeability). (9 – Yakima County)**

    USGS Particle Tracking Model Overview – potentially combined with MT3D MODFLOW application to the vadose Zone.

49. **Amend the Dairy Nutrient Management Act to extend WSDA's authority to manure application on properties other than those owned by dairies, provide more complete disclosure of Nutrient Management Plans. (8 – WSDA)**
50. **Provide assistance to local departments of health regarding the regulation of agricultural composting operations. (7 – Ecology)**
51. **Document and publish regulatory compliance for dairies within the GWMA that are completing and implementing Dairy Nutrient Management Plans (DNMP). (7 – WSDA)**

    Explore the possibility of disclosing non-proprietary data produced through the DNMP process. Summarize the DNMP reporting and provide information that would disclose the amount of manure the CAFO's in the GWMA create and where it is distributed.

52. **Assess Nitrogen Loading. Building from the WSDA's Nitrogen Availability Assessment, develop a Nitrogen Loading Assessment for all agricultural, residential and commercial properties, using newly collected data. (5 – WSDA, Ecology and Yakima County)**

    Hire a technical consultant to conduct a literature review to determine the most relevant information and accurate factors for use in the Nitrogen Loading Assessment. Periodically repeat the grower survey used in the NAA to compare against currently established data. Collect data on how many acres in the GWMA are fertilized in various crops with manure and/or commercial fertilizer. Update and monitor the percentage of acreage in various crops, particularly silage corn and field corn. Study effect nitrogen contribution from cover crops. Determine acreage for triticale. Discover commercial fertilizer tonnage for Yakima County and/or for GWMA. Explore how much nitrogen leaches into groundwater from drains and wasteways. Study atmospheric deposition more comprehensively. Understand the difference between plant uptake and plant removal of nitrogen. Ask EPA to use its CMAQ model, or other tools, to estimate emissions of reactive nitrogen - gaseous nitrogen oxides (NOx), ammonia ($NH3$), nitrous oxide ($N2O$), the anion nitrate, $NO3$,- from animal agriculture, manure and fertilizer applications. Use this to inform the nitrogen balance database and refine estimates of atmospheric deposition.

53. Issue permits for agricultural composting operations, to appropriately inspect composting operations and to enforce regulations that protect public health and the environment, per WAC 173.350.040. (4 – Yakima Health District)

54. Make capital improvements. (2 – Livestock producers)

Install liners in liquid manure storage lagoons. Install impervious surfaces beneath silage storage.

55. Inspect, monitor, and regulate stockpiled manures. (1 – Ecology)

Coordinate with WSDA. Currently being done; currently required as part of dairy nutrient management plans.

Draft Recommendations:

(Obtaining a Total Value of Zero or Less)

56. Make shallow (1, 2, 3 foot) soil testing reports prerequisites for funding, lending or building permits. (0 – Washington State Legislature)

In the nature of Phase I Environmental Audits. Make nitrate-related information/data available for water quality management.

57. Revise WAC 246-203-130 (keeping of animals) (-1 – DOH)

So that it includes specific and enforceable requirements designed to protect health.

58. Require facility process improvements in waste treatment and food processing plants to reduce nitrogen and total discharge volume. (-3 – Ecology)

Addressed by Department of Ecology General Permit for Food Processing, specific problems can be addressed through "special protection areas," WAC 173-200-090.

59. Improve composting regulations (statutory) (-4 – Ecology, WSDA)

Unclear as to particular regulations proposed.

60. Establish a monitoring system for compliance with NRCS Standard 317 on new composting facilities at Washington dairies (phased in for existing facilities). (-4 – WSDA)

61. Develop educational materials that could be elected by instructors at 8-12 levels about aquifer protection, groundwater and BMP. (-6 – WA

Superintendent of Public Instruction and Educational Service District 105)

62. **Require commodity commissions to dedicate "check off" money for research and development in water quality technology and practices. (-7 – Washington State Legislature)**
63. **Estimate emissions of reactive nitrogen – gaseous nitrogen oxides (NO_x), ammonia (NH_3), nitrous oxide (N_2O), the anion nitrate (NO_3) – from animal agriculture, manure and fertilizer applications in the Lower Yakima Valley. (-33 – Ecology, Yakima Clean Air Agency, and WSDA)**

    Use this to inform the nitrogen balance database for the GWMA area and refine estimates of atmospheric deposition.

64. **Study the relationship between nitrogen emissions and atmospheric deposition of reactive nitrogen. (-37 – Ecology and EPA)**

    Develop a model that predicts what percentage of emissions return to the GWMA area as atmospheric deposition.

Implementation Work Plans

This program is the plan for implantation. There are many aspects of the plan, including alternative management strategies as presented in the recommendations section. This follows the recommended general framework guidelines listed in WAC 173-100-100. A comprehensive list of alternative management strategies are contained in Appendix I. Additionally, the recommendations received during public comment of this program are contained in Appendix K.

Parties Responsible for Implementation of the Recommended Actions

The parties responsible for implementation of the recommended actions include:

- Yakima County
- Washington State Department of Ecology
- Washington State Department of Agriculture
- Washington State Department of Health
- Washington State Conservation Commission
- South Yakima Conservation District
- Washington State University Extension Service
- Agricultural Producers
- Roza-Sunnyside Joint Board of Control
- Yakima Health District

The Lower Yakima Valley Groundwater Management Program is intended to provide a framework to assist cooperation between affected agencies and private citizens through implementation of adopted management strategies.

Management Committee

While permanent funding sources are secured, a facilitation team should be formed to begin water protection activities in the GWMA. Representation should consist of a core committee of 6-8 members representing entities identified as responsible for implementation; Yakima County, Yakima Health District, Department of Health, Department of Agriculture, South Yakima Conservation District, Irrigation Districts, WSU Extension, Agricultural Producers, and Department of Ecology.

The team will identify the management structure best suited to meet the long-term goals of the implementation plan.
The final structure may include one of the following:
1) Lead Agency with full responsibility to implement;
2) A single agency acting as a Program facilitator (responsible for promoting communications between the agencies); or
3) Joint leadership committee comprised of the agencies authorized to carry out specific measures called out in the program.

The facilitation team should develop a set of roles and responsibilities in implementing, tracking the implementation, and periodic review of the Program as required in the WAC.

Implementation Functions

The Implementation committee may perform any of the following functions:

- Seek and administer funding for the accomplishment of recommendations made by the final GWMA Program.
- Encourage local, state and federal agencies to perform those activities recommended by the final GWMA Program.
- Maintain the GWMA website including the developed GIS database on the GWMA.
- Participate in educational activities in partnership with other appropriate agencies in a manner consistent with GWMA recommendations.
- Collect water quality data from the ambient groundwater monitoring wells installed in 2018.
- Collect data to track water quality improvement progress and nutrients generated, applied, or exported within the GWMA.
- Describe the characteristics of groundwater.
- Analyze nitrogen availability periodically, at least equivalent to WSDA (2018), in order to compare and contrast changes over time.
- When appropriate, call upon citizen involvement in decision making.
- Report at least triennially on the status of groundwater quality within the GWMA.
- Recommend strategies to mitigate adverse effects to groundwater quality within the GWMA.

- Develop and implement an Adaptive Management Plan within the GWMA.

Schedule For Implementation Of The Recommended Actions

Those recommendations based upon the implementation of Best Management Practices by agricultural producers should begin immediately.

Those recommended actions that depend upon the availability of public funding will likely require one to two years lead time to secure that funding prior to their implementation.

Those recommended actions that collect data over time, including the proposed Ambient Water Quality Monitoring Well Program, or voluntary Deep Soil Sampling Program, will be implemented over time.

These recommended actions and the program plan will be periodically reviewed.

Monitoring System For Evaluation Of Effectiveness Of Recommended Action

The Ambient Water Quality Monitoring System is comprised of 30 randomly placed, water table elevation groundwater quality monitoring wells. Data from these wells will be collected sufficiently often to track seasonal variation and general water quality over time.

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